



XIVth International Colloquium on Soil Zoology and Ecology
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➤ Abstracts

CONTENTS

SESSION 1 – *Man and the Soil Fauna*

Oral Contributions.....	3
Poster Contributions.....	6

SESSION 2 - *Soil Biodiversity*

Oral Contributions.....	8
Poster Contributions.....	15

SESSION 3 - *Soil Animals, Nutrient Cycling and Soil Fertility*

Oral Contributions.....	81
Poster Contributions.....	88

SESSION 4 - *Ecosystem Engineering by Soil Fauna*

Oral Contributions.....	110
Poster Contributions.....	117

SESSION 5 - *Food Webs and Other Nested Biological Controls*

Oral Contributions.....	148
Poster Contributions.....	155

SESSION 6 - *Soil Animals, Waste Treatment, Detoxification and Bioremediation*

Oral Contributions.....	178
Poster Contributions.....	186

SESSION 7 - *Functional Groups and Valuation as Indicators of Soil Fauna*

Oral Contributions.....	224
Poster Contributions.....	232

SESSION 8 - *Autecology and Biology of Soil Animals*

Poster Contributions.....	297
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SPECIAL SESSION - *Invasive Earthworms*

Oral Contributions.....	318
Poster Contributions.....	322

Author Index	329
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SESSION 1

Man and the Soil Fauna

ORAL CONTRIBUTIONS

The values of soil animals for conservation biology

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It has taken time for the international community to accept the idea of biodiversity values, a concept otherwise long term restricted to the limited aesthetic and touristic aspects of wildlife. This situation has changed, mainly since the International Convention on Biodiversity in Rio de Janeiro (1992), which focussed on “the forgotten environmental problem” of biodiversity erosion and made the first clear reference to the values of living species. Biodiversity values refer to the direct or indirect, economic or non-economic interest a given species or ecosystem may represent for human populations. These values are generally split into intrinsic and instrumental (use) values, the last category being itself divided into direct and indirect economic values. Obviously, each of these values carry different weights, and may not be considered as equally powerful in terms of justification for species or ecosystem conservation.

Soil is probably one of the more species-rich habitats of terrestrial ecosystems, especially if extending the definition of soils to related habitats like vertebrate faeces, decaying wood, humus of hollow trees. The diversity of soil communities (*sensu lato*) thus probably encompasses a large part of terrestrial animal species. This highly speciose fauna has been extensively studied by the scientific community, and current trends in soils fauna studies include aspects of biology, autecology, ecotoxicology, functional ecology. During the past 20 years, the recognition of the importance of soil fauna in the functioning of soils and by extension of terrestrial ecosystems has been continuously growing, ending in some important applications in agronomy and the research of sustainable systems of agricultural production.

Despite this general agreement about the ecological importance of soil fauna and its economic consequences, this group has been conspicuously mistaken in biological conservation studies. This paper aims at presenting soil fauna within the scope of conservation biology concepts, trying to identify the different values of soil fauna and how they rely to key ecosystem services. The enormous gap between their recognised usefulness and their consideration in protection policies is finally discussed.

Spatial aspects of soil fauna activities

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Recently, there is an increasing interest in spatial ecology. This is also caused by the increasing utilization of space by human activities and the competition between different forms of space utilization. Furthermore, there has been suggested that there is an important relation between spatial heterogeneity and biodiversity (a.o. Giller, 1996).

In a forest soil the spatial variation in soil processes, such as nitrogen and carbon mineralization, has been related with the bacterial composition, focussing on the diversity of ammonia oxidising bacteria, and the characteristics of the complete food web community, using the Geographical Information System (GIS) techniques.

“Hot spots” could be visualized, with high process activities and specific food web composition.

The consequences of spatial scaling on the quantitative relationships between habitat area, species diversity and food web interaction (Brose et al, 2004) will be discussed.

SESSION 1

Man and the Soil Fauna

POSTER CONTRIBUTIONS

The possibilities of usage of the earthworm *Eisenia fetida* (Sav.) biomass gained in ecological boxes in breeding of aquarium fish

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Earthworm ecological boxes provide one with the opportunity of home/school organic wastes utilisation on the spot of their origin. This solution adds to the initial waste segregation and decreases the amount of organic waste passed to waste dumping sites. Apart from that, the one carrying out the process of vermicomposting in ecological box, gains several other profits such as the possibility of using the produced vermicompost to fertilize home plants (horticultural usage of vermicompost) and regular receiving the earthworm biomass.

The aim of the research was to find further arguments advocating the idea of vermicomposting in household and school conditions. The alternative use of *Eisenia fetida* biomass covered in the paper was feeding aquarium fish on it.

Two species were subject to examination: *Poecilia reticulata* and *Xiphophorus hellen*, both chosen due to their common usage in household and school conditions. These are ovoviviparous species, easy to breed and having a short reproductive cycle. Each species was bred in two groups, with 6 specimens of both genders each.

The controlled group was made up by fish fed on standard food (*Daphnia*) and Biovit by Tropical company. The second group of fish was fed on Biovit and earthworms' biomass. The fish breeding was carried out in laboratory conditions, with 12 hours lighting cycle and constant temperature 24°C (water pH = 8).

The earthworm biomass was given to mature fish as small specimens, the brood was fed on ground biomass. The experiment lasted for 6 months.

As an effect of the experiment, it was noticed that the biomass of the earthworms produced in earthworm ecological boxes can be used for feeding aquarium fish. Comparing to those fed on standard food the fish increased the brood number as well as the maturation rate and mass.

Key words: Earthworm ecological box, *Eisenia fetida*, earthworm's biomass, bait, fish food, *Poecilia reticulata*, *Xiphophorus hellen*

SESSION 2

Soil Biodiversity

ORAL CONTRIBUTIONS

Resilience of soil mesofauna communities; does community stability depend on species richness?

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The notion that community structure affects temporal changes in the community and its constituent species dates back to the mid-1950s. However, if communities rich in species are more resilient, i.e. have a faster rate of return to equilibrium after disturbance, compared to species-poor communities is hardly known. The aim of this study was to test if resilience is causally related to species richness and to reveal the possible mechanisms behind such a relationship by focussing on the species identities in the community.

Intact soil columns (n = 2160) with a moist peaty clay soil were taken from a Junco-Molinion grassland. After differential defaunation, to take out mesofauna and macrofauna, new communities were established in the columns with an increase in mesofauna species richness, i.e. 0, 1, 2, 4, and 8 species (equal biomasses). The type of design is a critical factor in determining whether or not a diversity effect on stability is detected. Therefore, all eight species were kept as a monoculture to measure their potential effect on community variables. The 2-species and 4-species treatments were replicated four times, each with a different species composition, to account for possible compositional effects. The selected species differed in body size, mode and frequency of reproduction, and vertical stratification. Moreover, all multi-species treatments contained a dominant species to overcome the 'selection probability effect'. The 18 different 'communities' were placed in the field in a randomised block design (n = 4 blocks), together with a control for each community (36 treatments, in 15-fold per block). After two years half the treatments were disturbed using CO₂ fumigation, which did not effect plants and soil structure but reduced community abundance by 50%. We quantified by destructive sampling the rate of recovery of the communities in comparison to the undisturbed controls, as a function of species richness and composition.

We observed a high resilience in mesofauna communities. Already after nine months the abundance and biomass of disturbed communities were equal to the undisturbed controls. However, after 16 months the species composition, i.e. the relative species abundance and biomass, was different between disturbed communities and the subsequent controls. Community composition at fixed diversity levels did not influence resilience. No correlation between community biomass or abundance and plant productivity or microbial biomass was found.

We believe that the observed fast rate of community recovery after disturbance can be explained by the time the disturbance was applied, just before egg hatching. The disturbance affected the adult stage but not the egg stage. Eggs of most soil animals are resistant to high CO₂ levels. Therefore, a second disturbance, a short but severe cold period which also affected the egg stage, was applied to the various communities. Resilience is now monitored. We expect the rate of recovery to be slower and species-specific effects and species richness effects to be more pronounced. The first preliminary results of this ongoing experiment let us to conclude that community stability, defined as resilience, does not depend on species richness.

Biodiversity of soil fauna and the importance of identification to species level

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The assessment of soil animal richness can be impeded by the lack of comprehensive, taxonomic keys for several groups in many of our regions (e.g. soil mites in the UK). However, progress is being made with some taxa, such as British springtails (Collembola). In this paper, we present an example of a dataset collected from the Soil Biodiversity Programme that aimed to ascertain the biodiversity and interactions involved in soil food webs. By identifying springtails to species, we demonstrate why it is important to classify fauna to this level in order to avoid misinterpretation of ecological data.

Surveying biodiversity of subterranean herpetofauna: qualitative, semi-quantitative and quantitative methods

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Soils have a high biodiversity of fossorial herpetofauna, including seven major squamate lineages (Gekkota, Dibamidae, Anguidae, Lacertoidea, Scincoidea, Serpentes and Amphisbaenia) as well as representatives from all three amphibian orders (Caudata, Anura and Gymnophiona). However, many species are known from very few specimens, and modern surveys of regional biodiversity are neglecting subterranean vertebrate taxa, or failing to find them, and classifying them as rare or endangered. Recent published work has recognised the need for standardised methods for surveying belowground reptiles and amphibians. Qualitative, semi-quantitative and quantitative methods are presented, with an emphasis on digging into the soil. An assessment of traditional, current and possible future sampling strategies is made. Results from surveys world-wide are presented, revealing densities of subterranean vertebrates as high as 1.87 individuals per m², and giving preliminary views on comparative taxonomic abundance, habitat and microhabitat preference.

This research was supported through a European Commission Marie Curie Fellowship: HPMF-CT-2001-01407.

Species richness and zoogeographic affinities of earthworms in Cyprus

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The East Mediterranean island of Cyprus (9,240 km²) is situated about 64 km east of the Turkish coast (Anatolian zoogeographic region) and 97 km west of the Syrian coast (Levantine zoogeographic region). The new survey of earthworms we conducted in Cyprus increased the number of earthworm species from the six recorded by Michalis (1993) to fourteen. These species belong to two earthworm families: Lumbricidae (13 species) and Acanthodrilidae (one species). The majority of these species are autochthonous (57-64%) and only five or six species (36-43%) are introduced (*Aporrectodea caliginosa*, *Ap. rosea?* *Dendrobaena veneta*, *Eiseniella tetraedra*, *Microscolex phosphoreus*, and *Octolasion cyaneum*). Autochthonous species are (i) endemic of Anatolia (*D. pantaleonis*), (ii) endemic of the Levant (*D. semitica*), (iii) distributed in Anatolia and Caucasus (*D. pantheri*), (iv) distributed from Europe up to Anatolia and from Europe up to the East Mediterranean (*Proctodrilus tuberculatus*, *Murchieona minuscula*), or (v) widely distributed more or less along the whole Mediterranean basin (*D. byblica*, *E. neapolitana*, and *Octodrilus complanatus*).

The obtained data indicate that the Cyprus earthworm fauna is significantly richer in autochthonous species than previously thought by Michalis (1993) and that it shows more affinities with the Anatolian fauna than with the Levantine one. No endemic earthworm species have been recorded so far in Cyprus, which might indicate that the earthworm fauna of Cyprus is relatively young. To the same conclusion points also the fact that only advanced autochthonous earthworm genera are present.

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The effect of plant diversity manipulation on the succession of soil fauna in an abandoned arable field

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In Europe, arable land is currently set aside to reduce overproduction of crops. However, management is still necessary in order to enhance plant succession towards a species rich, weed resistant, plant community in restored land. The purpose of this study was to assess the effect of plant community management on representative groups of soil fauna.

A field experiment was set up in an arable land in Southern Bohemia, Czech Republic, in spring 1996. It was organised in a randomised block design with five blocks as replicates. Within each block, there were four plots 10 x 10 m, one for each treatment. Following treatments were used: continued crop rotation (CCR), natural colonisation (NC), low diversity seed mixture (LD), or high diversity seed mixture (HD). In the LD plots, a mixture of late successional grassland species was sown consisting of two grasses, one legume and one other forb species. In the HD plots, the sown mixture consisted of five grass species, five legumes and five other forbs. Seed mixture composition and density of seeds of individual plants used in particular blocks of LD treatments and in HD plots are described in Lepš et al. (2001).

Soil samples were taken in May and November 2002, i.e. after seven years since establishment of the site. Selected groups of soil animals (testate amoebae, oribatid mites and earthworms) were extracted using standardised soil zoological methods and identified at the species level. In addition, chemical soil parameters were measured (pH, K, Ca, Mg, different forms of P, Cox).

There were no differences among treatments in soil parameters. Diversity and density of testate amoebae was significantly lower in CCR ($H' 1.39$, mean density $18 \times 10^3 \text{ ind.m}^2$) than in other treatments (no significant differences between NC, LD and HD; H' ranging from 1.69 to 1.85, density from 32 to $49.5 \times 10^3 \text{ ind.m}^2$). Representatives of *Plagiopyxis* and *Trinema* amoebae predominated in all treatments. Eighteen species were identified among 3,489 individuals of oribatid mites collected. There were no differences among treatments in both numbers of species (9) and dominants (*Tectocepheus velatus* and *Microppia minus*) of oribatid mites. Their density was highest in CCR ($8,960 \text{ ind.m}^2$) and the lowest in HD ($2,440 \text{ ind.m}^2$). Five species of earthworms were identified from all treatments. There were however remarkable differences in the community structure of earthworms between CCR, where endogeic *Aporrectodea caliginosa* dominated, and other treatments, where epigeic *Dendrobaena octaedra* highly predominated. Treatments differed significantly in earthworm density (the lowest in CCR - $76,9 \text{ ind.m}^2$, the highest in HD - $413,6 \text{ ind.m}^2$). The study showed that the abandonment of intense agriculture led to significant changes in soil fauna. However, the response to the management of plant community differed among individual groups of soil animals.

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Community assembly of terrestrial testate amoebae – is there any succession at all?

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“Succession” is characterised by a temporal replacement of taxa during the process of biodiversity development. Heterotrophic protists play an important part in primary succession, because it is assumed that the first eukaryotic organisms arriving at newly exposed land surfaces are protists facilitating the establishment of plants and animals (Hodkinson et al. 2002). Especially testate amoebae are one of the very first colonizers (Wanner et al. 1998), which may be responsible for future patterns in biodiversity development by e.g. deposition of organic matter or nutrients. We investigated testate amoebae from inland dune soils which revealed high abundances even at very dry sites. Their species number increased significantly with the successional stage of the vegetation cover, but no replacement or change of taxa was observed. This points to a lack of a “real” succession and is corroborated by immigration experiments. Organism-free substrates exposed to the air or adjacent soil were colonized quickly by testate amoebae, but no temporal replacement of species occurred. Furthermore, not only the source pool of potential immigrants, but also the quality of the implanted target substrate was decisive for the further development of the amoeba community. This kind of community assembly is characterised by an “additive colonization” (Wanner & Dunger 1999) rather than a “succession”. Further investigations have to clarify if and how competition affects amoebal colonization of newly exposed substrates. Are there any “assembly rules” responsible for a distinct pattern in amoebal biodiversity development?

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SESSION 2

Soil Biodiversity

POSTER CONTRIBUTIONS

Dynamics and activity of Protozoa abundances and functional groups in succession chronosequences

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Most studies of Protozoa in the soil are based on “most probable number” (MPN) estimates from cultured sub-samples. This approach has been criticized in recent years by protistologists. In order to work around these criticisms, we have tried to develop a set of procedures that rely on active species, without culturing. We show that the method is more sensitive than the MPN approach. Protozoa were enumerated by direct count at the microscope in a series of observations from soil samples.

In a first set of observations, soil samples were obtained from an agricultural and a forest site, at 2-3 day intervals, to monitor changes in abundance and species composition with changes in weather and soil moisture/temperature. The agricultural site was located in the southern USA, at Athens (Ga) and the forest site was located in North Carolina at the Coweeta research forest. The observations were repeated in the fall, winter and summer. We found a good fit between soil moisture changes and the abundance of nanoflagellate bacterivores on bacteria. Different taxonomic groups were active as soil moisture changed over several days. Some species of amoebae became dominant in drier conditions. Ciliates were always present at very low abundances.

In a second set of observations, we followed changes in the activity of Protozoa in leaf litter bags over 12 months on the forest floor. Litter bags containing oak, rhododendron or tulip poplar recently senesced leaves were collected at the Coweeta forest. Succession of active Protozoa was different between each of three leaf litter species, but similar within litter species, over the twelve months study. We observed both a seasonal effect for some taxa, and a successional sequence that seemed to follow litter chemistry changes. Comparing the sequence of litter chemistry changes and species abundances, we constructed a successional series of Protozoa on leaf litter.

We found that direct count methods, without prior culturing of samples, were sensitive in detecting changes over several days and over several months, from field samples. This provides a great advantage over culture based methods that generally fail to distinguish between encysted and re-activated species.

Modelling spatial distribution of earthworms in homogenous chalky tall grassland: an individual-based approach

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Spatially explicit sampling of earthworms on chalky slopes of the Seine valley in physiologically homogeneous tall grassland (Mesobromion) have been conducted at 5 dates on a square pattern of 100 plots, on a square 2-meters mesh lattice.

Geostatistical and SADIE analyses showed the presence of significant spatial patterns at a range of ca.12 m, with alternating patches of high and low densities.

An Individual-Based Model was built in order to determine whether these patterns could be modelled by a single species dynamic or whether they were due to inter-specific interactions. The dominant species *Allolobophora chlorotica* in both cases was chosen as referent for testing the model. Demographic parameters values were found in literature and field data collected during two years monthly survey were used for calibrating these parameters. Sensitivity analyses were conducted to determine the stability of the model and to study the links between state variables. To match with field data scale, we built a 200 * 200 toroidal square lattice in which each individual cell was assumed to represent 1/16 of square meter. Each individual was allowed to move on the lattice with a random walk procedure. At each time step, these events were applied to each individual: movement, mortality, reproduction, feeding, growth, quiescence. Movement, mortality and part of reproduction process were probabilistic events whereas others were deterministic. Resource was assumed to follow a logistic growth. The model outputs were produced as maps of earthworm densities and analysed with the same tools as those used with field data. The presence of probabilistic events drove us to run 100 iterations of each set of parameters.

The model mean analysis was compared with field data analysis. Geostatistical and SADIE analysis of model outputs matched those of field data, allowing us to hypothesise that *A. chlorotica* spatial pattern are mainly explained by single species dynamic and weakly dependant of other earthworm species dynamics.

Comparison of termite species richness, composition and diversity in the natural reserve of Lama and its surrounding teak plantation (Bénin)

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Termites play an important role in the tropical ecosystem and have been identified as a potential indicator of biodiversity. This study establishes preliminary termite inventories conducted in 2002 in the Lama forest reserve (Southern Benin), one of the last remnants of natural forest in the Dahomey gap, and investigates the effect of the conversion of natural forest to teak plantation on termite species richness and functional diversity. Samplings was conducted in the natural forest and in the 15 years old teak plantation using the standardized 100 m x 2 m transect method and each habitat was replicated four times.

Data showed a reduction of species richness in the teak plantation surrounding the natural forest. The feeding group I termites (wood feeders Kalotermitidae) predominated in the natural forest sites but were absent in the teak plantation sites. The termite feeding Groups II and III (litter feeders, grass feeders and very decayed wood or high organic content soil feeders Termitidae) did not seem to be affected by the conversion of natural forest to teak plantation and appear to have similar species richness in both habitats with the litter/wood feeder *Macrotermes bellicosus* appearing to be present only in the teak plantation. True soil feeder termites were not recorded in the Lama forest reserve during this survey and we speculate that this may probably be a characteristic of the cracking vertisol present in this ecosystem.

Key words: Lama forest, species richness, feeding group, nesting group, wood feeders, teak plantation, termites

Factors controlling soil macrofauna spatial pattern in a pure beech and a mixed beech-hornbeam forest (Upper-Normandy, France)

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At stand level, we investigated factors controlling soil macrofauna spatial pattern under a pure beech (*Fagus sylvatica* L.) and a mixed beech-hornbeam (*Carpinus betulus* L.) stand. Contrary to beech, hornbeam has a litter of better quality with low polyphenols concentration. According to the hierarchical model of factors controlling organic matter decomposition processes in terrestrial ecosystems (Lavelle et al., 1993) we hypothesized that under mixed stand (MS), macrofauna spatial patterns are controlled by the litterfalls i.e. *distal control* (external to humic epipedon) and under pure stand (PS), they are controlled by micro-organisms activity i.e. *proximal control* (internal to humic epipedon) estimated through macro-morphological and chemical humic epipedon properties.

In each stand, soil macro-invertebrates was sampled by hand sorting 121 (25 x 25 x 30cm) soil monoliths regularly distributed on a 10 m mesh (100 x 100 m) squared grid. Humic epipedon morphological and chemical properties, relative irradiance, soil bulk density and the specific composition of OLn in MS were also investigated. Detritivorous were identified at the species level while the other macro-invertebrates were identified at the family level. Environmental variables – soil macrofauna relationships were analysed by co-inertia analysis. LOWESS regressions were used to assess variation patterns of detritivorous density, species richness (SR), Shannon index (H') and Evenness (J') along the first co-inertia axes.

The total taxonomic diversity was nearly similar on both sites. Nonetheless, the average diversity by sample was greater under PS. Average sample density was also greater under PS than under MS. Detritivorous communities exhibited similar trends. Co-inertia analysis performed on PS data revealed that the main factor explaining soil macrofauna spatial distribution was humus form activity. Under MS, this factor was revealed as a second order determinant and the main explicative factor was the litter quality i.e. opposition between hornbeam litter and beech litter. Lowess regressions performed between (i) the sample scores on the first co-inertia axis and (ii) detritivorous SR, H', J' and density revealed: (i) Under PS, SR and H' tended to increase when humiferous episolum increased; and (ii) under MS, SR, H' and detritivorous density exhibited the highest values when 25% of hornbeam leaves were present in OLn.

The highest average density and taxonomic richness by sample under PS can be explained either by (i) moder humus forms predominance under PS, which can provide a more suitable habitat; or (ii) the impact of the last canopy thinning operation, which occurred in 1998 for MS and 1995 for PS.

At stand level, our results seemed to validate the initial hypothesis that macrofauna spatial variability depended on a proximal control (i.e. internal to humic epipedon) when litter quality is uniform and a distal control (i.e. external to humic epipedon) when the quality of litterfall is variable.

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Colonizing the canopy: are oribatid mites tree specific?

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A diverse assemblage of oribatid mites inhabits the canopies of coniferous trees in western North America. The mites utilize resources that are similar to those exploited by species in forest floor soil and litter. These communities are discrete from those of the forest floor, which has been used to argue for the conservation of old-growth forest without explicit evidence that oribatid species are tree specific. We tested the hypotheses that oribatid mites are both tree specific and microhabitat specific in old-growth (200-500 year old) Douglas fir (*Pseudotsuga menziesii*), Western hemlock (*Tsuga heterophylla*) and Western red-cedar (*Thuja plicata*), at the Wind River Crane Research Facility in Gifford Pinchot National Forest, Washington, USA. Arthropods were extracted from alecteroid and foliose lichens collected from canopies of the three tree species. Samples were dominated by Oribatida both in abundance and species richness. Overall oribatid species richness was low, 16 species in 11 families, with no species unique to this site. Oribatid abundance and species richness was highest in foliose lichens. Oribatid abundance and assemblage structure were both microhabitat specific and tree specific. All oribatid species were obligate canopy inhabitants, and were absent from Berlese samples taken contemporaneously from adjacent forest floor soil and litter. The results support using oribatid abundance and assemblage structure for assessing forest conservation needs. They also argue for sampling multiple microhabitats when assessing overall canopy biodiversity.

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Soil macroinvertebrate community diversity in native Atlantic Forest and agroecosystems in Londrina, Paraná State, Brazil

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The soil macrofauna, comprised of invertebrates >2mm, includes both beneficials and pests of agricultural crops (e.g., termites, ants, earthworms, beetle white-grubs, true-bugs, snails, millipedes, centipedes, spiders, crickets, larvae of insects and others). Their diversity tends to be low in highly-disturbed systems such as those with conventional tillage (CT) and pesticides, but can be increased with appropriate soil and ecosystem management, including organic matter addition, no-tillage or direct drilling (NT) and crop rotations. Their activity is important for soil physical, chemical and biological properties and processes and also for plant growth and ecosystem productivity. Studies on the soil macroinvertebrate communities in the region of Londrina began in 1998, in private farms and research trials with different crop management systems. Soils of the region are primarily clayey (>65% clay) dystrophic or eutrophic Red Latossols (Oxisols and Ultisols). Samples were taken in summer (mainly soybean) and winter crops (mainly wheat and oats) under various tillage and crop management practices (including NT and CT) and in native forests, using the TSBF (Anderson and Ingram 1993) methodology. The total number of morphospecies, orders and N° taxonomic groups sample-1 were measured per land use system.

In the native Atlantic Forests, total group diversity ranged from 25 to 27 taxonomic orders, and total diversity ranged from 82-126 morphospecies. The number of orders per monolith ranged from 13-18, indicating high diversity per sample, and a more even distribution of the diversity over the sample area. Ants and termites predominated, and the most diverse group were the ants (11-22 morphospecies), followed by beetle adults (13-19 morphosp.), beetle larvae (12-13 morphosp.) and spiders (8-11 morphosp.). In the agroecosystems, total group diversity was much lower, ranging from 12-13 orders in CT to 16-18 orders in NT and minimum tillage (MT). The number of orders per sample was also lower, ranging from 6-7 orders in CT and 10-11 orders in NT and MT.

Studying the community composition of the soil fauna is important for the holistic understanding of the soil and its function, since the equilibrium/disequilibrium processes of these communities can result in the explosion of pests, the loss of good soil physical structure, soil fertility and productive potential. So far, very few measurements of the soil fauna communities and their diversity in agricultural systems have been performed in Brazil and, due to their importance for soil function (e.g., pest or ecosystem engineering effects, *sensu* Lavelle et al., 1997), these organisms deserve more attention.

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Ant Diversity in Secondary Forests of the Mata Atlântica in Brazil – Methods and Approaches (Project SOLOBIOMA)

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Destruction of pristine natural habitats is one of the most serious ecological problems at present. More than 90% of the Brazilian Atlantic rainforest biome (Mata Atlântica) has been degraded or destructed by man and to the hitherto existing state of knowledge this leads to severe consequences for the regional biodiversity. Current understanding about the extend to which regenerating forests can serve as species refugia for forest species is poor. An improved understanding of the relationships between soil biodiversity and habitat heterogeneity is needed to predict the impacts of human activity on ecosystem processes, to manage soil communities, and to assure soil sustainability for the future.

Ants (Hymenoptera, Formicidae) as the dominant group of terrestrial arthropods in the tropics have been chosen to investigate the influence of anthropogenic disturbance on soil biodiversity in secondary forests of the Serra do Mar in Paraná, Brazil. Ants are important ecologically because they function at many levels in the soil ecosystem – as predators and prey, as decomposers, herbivores and mutualists and many act as “ecosystem engineers” because of their soil moving activity and concentration of nutrients in and around their nests.

Objectives of our research are to understand (1) how the ant community of the soil and litter layer (species richness, diversity, morphology) is composed in forests of different age and therefore different structure representing regeneration stages from former pasture and (2) how soil conditions (well drained cambisols vs. water logged gleysols) influence the anthropogenic impact.

To achieve this aim we established 27 sampling sites in the “Reserva Natural do Rio Cachoeira” representing three replicates of three different forest ages on both cambisol and gleysol. Potential study sites were selected by an intersection of digital vegetation and soil maps of the area using GIS software (ArcView), followed by validation of site conditions in the field. For comparison reasons also three replicated sites have been sampled in pastures on both soil types and in old growth forest on cambisol.

At each sampling site ants of the soil and litter stratum were sampled at 20 evenly spaced sampling points along two parallel 50 m transects. At every sampling point ants were collected from litter samples (Winkler method), soil samples (Berlese extraction) and underground baits. For each of the study sites we also assessed basic biotic (vegetation structure, litter volume) and abiotic attributes (physical and chemical soil properties, microclimate) which will facilitate the interpretation of the observed diversity patterns across sites.

The long term objective of our project is to understand the role of secondary forest as species refugia and hence providing ecological basics for the conservation management of biodiversity in the Mata Atlântica.

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New insights into the biogeography of soil mites and collembola from the Countryside Survey of Great Britain

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With the increasing interest in the importance of soil invertebrates to the maintenance of soil quality and the intrinsic value of soil biodiversity *per se*, soil ecologists are being asked to inform policy-makers on the occurrence and distribution of soil invertebrates at a range of geographical scales, and what might influence these patterns. However, the data needed to answer these questions are generally lacking (RCEP, 1996). As a result of a national-scale initiative, Countryside Survey 2000 (CS2000), we obtained data for a range of biological, chemical and physical properties of soils, in combination with detailed site characteristics (e.g. geographical location, altitude, vegetation, land use, pollutants, etc.) from over 1200 locations across Great Britain (Black et al., 2003). As part of this initiative, we identified and counted soil invertebrates from Tullgren funnel extractions, including species identification of Oribatid mites and collembola. Results from multivariate data analyses reveal new insights into the biogeography of the two dominant groups of soil invertebrates from CS2000, mites and collembola, including the relative importance of vegetation type, soils and land use in determining the occurrence of species and community structure of soil microarthropods.

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Present state of the art of earthworm taxonomy and ecology in the State of São Paulo, Brazil

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The state of São Paulo (SP) is the most urbanized, industrialized, richest and populous (35 million) state in Brazil. The state's approximately 250,000 km² are mostly used for agricultural purposes and human occupation. Only 13% is in native vegetation, concentrated in forests (11%), cerrado and other vegetation (1% each). Of the remaining forests, 60% are concentrated on the coastal range, and 40% highly scattered in many small pieces throughout the remaining area. The taxonomist Gilberto Righi lived and worked in SP, describing, over 40 years of work, more than 230 earthworm species. The study of earthworm taxonomy and ecology in SP is the most extensive in the country. However, only 16% (106) of the 645 counties of SP have been sampled for earthworms. At present, 64 species are known from SP, but at least another 26 are expected to be found, according to Righi, who predicted 90 species for SP. Of the 64 known species, 44 are native and 20 are exotic, and 32 are known from only 1 location, while 12 are known from 2 sites. This may be due either to a large endemicity of native species or too few samples to adequately assess the nature of species distribution in SP, further accentuated by the extremely fragmented nature of the natural vegetation, where native species are most often encountered. Of the native species, 38 are of the Glossoscolecidae family and eight of the Ocnerodrilidae family. Of the exotics, seven are Megascolecidae and six are Acanthodrilidae. The most widespread species is *Pontoscolex corethrurus*, found in 64% of the samples, in a wide variety of natural and disturbed ecosystems, and appears to be a good indicator of disturbance. This species has been the most studied in SP, for evaluation of life-cycle under laboratory conditions, effect on soil microorganisms and on soil nutrient status and plant productivity. Other work in SP has involved mostly practical and empirical observations of the vermi-composting process with the exotics *Eisenia fetida*, *E. andrei* and *Eudrilus eugeniae*.

Quantitative samples to assess population density and biomass were taken in 57 sites of SP, concentrated mostly in the NW part. These showed that: a) earthworms were more abundant in no tillage systems than where the soil was tilled; b) the best sample size for population estimation was 60x60x60 cm; c) formalin application was not efficient for collecting native earthworms; d) soil moisture and soil type had a major influence on earthworm species composition and population density; e) *P. corethrurus* concentrated in areas that were more shaded and closer to trees.

Clearly, there is still much to be done to adequately assess the diversity and role of earthworms in the various ecosystems of the state of SP and, given that no taxonomist is presently active in the country, training of new taxonomists is an utmost necessity.

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Soil macroinvertebrate populations and their seasonal dynamics in a native pasture at La Víbora (VER) Mexico

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The soil macroinvertebrate community, comprising all easily visible organisms found in the soil were sampled by handsorting throughout a one-year period in a seasonally dry, native grass pasture located near La Víbora, Veracruz, Mexico. Annual rainfall was 1420 mm, of which 84% is concentrated between the months of June to October. Each month 25 samples (25x25 cm, 20 cm depth) were taken and sorted manually in the field. A total of 10 monthly samples were taken between June 1996 and May 1997. Earthworms were collected, weighed wet, preserved in 10% formalin and then separated into species and re-weighed, while the remaining fauna were collected, preserved in 70% alcohol, separated into taxonomic orders and weighed wet. At each sample date, soil moisture and pasture biomass (green, dry, shoot and root) were also measured.

The results show that soil moisture, green shoot biomass and soil fauna biomass (espec. earthworms) followed a similar pattern, with maximum values in the mid-end rainy season and minimum at the end of the dry season. Total fauna biomass ranged from a minimum of 1.3 g m⁻² late in the dry season (early June) to a maximum of 49 g m⁻² in mid-rainy season (September). Earthworms generally dominated the total biomass, especially in the rainy season (July-November), when they contributed more than 80% of the total. In the dry season, earthworm contribution dropped to less than 30%, when the contribution of beetles (larvae and adults), ants and lepidoptera larvae concomitantly increased, reaching up to 60% (Coleoptera in June).

Total abundance ranged from a low mean value of 109 individuals m⁻² late in the dry season (May) to a maximum of 452 individuals m⁻² late in the wet season (October). As with biomass, coleoptera and ants (up to 75% in June) represented the majority of the total density in the drier periods, while earthworms contributed from 28-84% in the wet season, and less than 25% (as low as 3%) in the dry season. Seven earthworm species, six native and one exotic were found. A new species of the Glossoscolecidae family was dominant in numbers and biomass, generally representing >80% of total earthworm abundance and biomass. Total diversity of groups (number of orders) was generally low on each sample date, rarely exceeding 7 orders. Highest total diversity was found in the mid-late dry season. The average number of orders per sample ranged from 2 to 5, being highest at the end of the rainy season (October), and the middle of the dry season (February).

Microhabitat preferences of Collembola, Aranea and Coleoptera in mosaic-like habitats in the Cinege Valley, Hungary

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The structure and ecology of Collembola, Araneae and Coleoptera communities were investigated in different habitats of Cinege Creek valley (Protected landscape area, South of Lake Balaton, West Hungary). The aim was – depending on the result of the investigation – to establish a separate local nature conservation and recreation area. The study area consists of 16 smaller habitats, which differ from each other in the composition of the vegetation and the water regime of the soils. Animals were collected from the selected sampling sites using mainly two different methods: 1) Separating animals with the Berlese method from A-horizon-soil and the litter. 2) Using pitfall traps containing ethylene glycol. Both species diversity and the frequency of occurrence (abundance) were highest in the oak forest and in the reeds, while the lowest on the area with horsetails and sedges. The community structures of collembolans, beetles and spiders in these different habitats were compared. The species compositions clearly reflected the microclimatic characters of the individual habitats. At the same time, also some rare species were identified from this area. We found some protected species as *Carabus convexus*, *C. coriaceus*, *C. germani*, *C. granulatus*, *C. nemoralis*, *C. schendreli*, *C. ullrichi*. Others (*Zelotes civicus*, *Z. hermanni*, *Abax parapellepipedus*, *Pterostichus oblongopunctatus*, *Micaria/Micariolepis dives*, *Oxiptila nigrita*) indicate the conditions and the value of the area. The result of our investigation proved that the small but diverse mosaic-like habitats could preserve a lot of valuable species. The smaller microhabitats offer good circumstances for the different species. Here the diversity could be high. The most important environmental factors were the humidity and the vegetation of the area.

Abundance, biomass and diversity of earthworm communities in forest and pastures of the Colombian Andes

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From July 1995 to February 1997, weekly samples were taken from forest and from pastures (*Pennisetum clandestinum*) in Andean hillside soils, Cauca, Colombia, characterized as Inceptisols and Andisols with very low natural fertility. This paper compares two earthworm communities, one in forest and the other one in pasture and examines their relationships with the soil. Earthworms were sampled for 19 months, two 1 x 1 x 0.6 m soil volumes were taken manually every week.

The amount of seasonal fluctuation varied between the two sites. In the forest, it ranged from 34 (July 95) to 127 individuals per m² (December 96). Biomass ranged among 112.6 (July 95) and 434.9 (August 96) g f m². There were more earthworms under pasture, where abundance ranged from 74 (December 1995) to 395 (April 1996) ind/m². Biomass was generally lower, from 9.4 (August 95) to 193 (April 1996) g f m m². The rainfall effect on populations was unclear; however, the abundance was lower in some dry months.

In the forest, the most abundant species were *M. heterostichon* (Schmarda, 1861) (55%) and *P. corethrurus* (Müller, 1856) (30%); while most of the worm biomass was *M. heterostichon* (92%), *P. corethrurus* was only 4 % of the biomass. Under pasture the most common species were *Glossodrilus* sp 1 (44%), *A. corticis* (Kinberg, 1867) (38) and *M. agricola* (Cognetti, 1904) (7); *A. corticis* (65) and New Gen sp 1 (15) constituted most of the biomass.

This study showed several natural and anthropic microcenters that offers the Andean mountain range as a place for shelter and diversity of earthworm species. It also emphasizes on the necessity of a biogeography program of soil macroinvertebrates and points out the need of creating a net of specialists of Oligochaeta taxonomy found in the neotropics.

Molecular phylogenetic analysis of common Megascolecidae earthworms in Japan

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Megascolecidae is the major family in Asian earthworm. Among them, *Amyntas* is the most dominant genus of Japan. Many species of them show a wide variation in their reproduction organs, which is the key characteristics for taxonomic analysis. Because of their morphological variation, *Amyntas* worms are divided into many related species, possibly 70 species or more. Two most common worms in central Japan are *Amyntas hilgendorfi* (Michaelson, 1892) (approximately 80% in wild population of ~10cm long) and *A. corticis* (Kinberg, 1867)(approximately 5%). Although *A. corticis* retains their male pores, more than 90% of *A. hilgendorfi* lost their male pores and many of them lost spermathecae as well. The incomplete gonad of *A. hilgendorfi* suggests the dysfunction of usual sexual reproduction in these animals. Thus, their taxonomic rationality is still in discussion. Molecular studies would help rationalize taxonomic analysis and reveal how the major species of wild *A. hilgendorfi* keep their population. Here, we collected *Amyntas* worms from the Kanto plate. The samples were morphologically examined. Ribosomal RNA genes were PCR-amplified from 50 worms, which belong to 9 species of *Amyntas* worms with several worms from each species. PCR products were directly sequenced. The analyses of 18S rRNA genes revealed high sequence identity within the genus. There was one variation for approximately 500-bps in the 5' region among 50 worms. However, this variation had no correlation with morphology. No sequence variation was found for-500 bps in the 5'-flanking region of the 28S rRNA gene. In contrast, mitochondrial genes for 12S and 16S rRNAs have more sequence variations. To evaluate these variations, molecular phylogenetic analysis was carried out using the NJ method together with the sequences of *Tubifex tubifex* subpopulations obtained from database. This analysis suggested that the distances within *Amyntas* worms are less than those within *T. tubifex* subpopulations. Taken together, our results suggest that *Amyntas* worms are genetically closely related, although they have a wide variation in morphology. To establish the phylogenetic relationship, it is necessary to clarify the genetic variations of these genes. Now, we are analyzing adjacent regions of these rRNA genes. In addition, the employment of RAPD and micro-satellite markers may help reveal their reproductive mechanisms.

The effect of soil formation on biological activity in the Makhtesh Ramon Crater, Negev, Israel

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Makhtesh Ramon (Ramon Crater) is known as one of the largest craters in the world, with a deep erosional basin 40 km long and about 12 km wide. It has developed in the Ramon anticline since the late Miocene period and is located in an arid to extremely arid climate. As a result of tectonic and climatic processes in this area, some rock strata were eroded in the upper levels. Soil formation processes that took place on the bedrocks were evaluated based on pollen and thermo-luminescence analyses, and it was estimated that they were formed 35,000-450,000 years ago. These findings enabled us to distinguish between the terraces according to bedrock age.

The aim of our study was to relate the soil free-living nematode population activity and soil abiotic composition to the soil formed on differently aged terraces.

Soil samples were collected monthly from 4 terraces aged: (1) 48,000-60,000 years old; (2) 100,000-110,000 years old; (3) 200,000-240,000 years old; and (4) 400,000 years old. Soil samples (n=5) were collected at each location from the upper 0-10 cm layers and soil environmental variables (soil moisture, organic matter, total soluble N) and nematode population were determined.

Preliminary results showed no significant differences in soil moisture, however, significant higher levels of total carbon were found in the younger terraces (0.66%) compared to the older ones (0.11%). Total soluble nitrogen showed a similar trend to that found for soil organic carbon, with levels of 60 and 40 ppm found in the younger and older terraces, respectively. Despite the above-mentioned abiotic variable, the total nematode population was found to be relatively higher in the older terraces compared to the younger ones.

Based on these preliminary results, we propose that terrace age differentially affects chemical and biological components.

Structure and spatio-temporal long-term changes in the diplopod soil community of a oak-hornbeam forest ecosystem (Fontainebleau Forest, France)

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The specific richness and biodiversity of a millipede community has been investigated during several years in a temperate forest area near Fontainebleau (France). Some changes in the organization and spatio-temporal composition of the diplopod population are presented and discussed. Noticeable differences in the relative abundance of specific populations between seasons and years can be emphasized.

The saprophagous diplopod guild in the Foljuif Forest Station include 17 species populations, among them five are dominant, such as *Glomeris marginata* (Villers, 1789), *Polydesmus angustus* Latzel, 1884 and *Melogona gallica* (Latzel, 1884). Two julid species, *Cylindroiulus punctatus* (Leach, 1815) and *Allajulus nitidus* (Verhoeff, 1891) show particularly remarkable changes occurring along the main investigated period (1975-1984). A progressive but partial replacement of *A. nitidus* by *C. punctatus* has been observed during a long-term study period (1975-1991), using different techniques: pitfall traps, hand capture in peculiar habitats and quantitative soil sampling. *C. punctatus* became largely dominant in soil and litter compartments and decaying logs (mainly oak and hornbeam) in which it partly took the place and function previously occupied by *A. nitidus*.

This tendency to a partial reorganization of the diplopod population has been checked ten years later in 2001, then confirmed in 2003.

Hypotheses taking in account natural events such as the utterly severe drought that occurred in spring-summer 1976 and evolving human activities in the area - enclosure of the study site and increase of wooden logs density - are proposed to explain the modifications in the diplopod community structure.

These investigations took place in a long-term period research programme about the functional biodiversity of macro-arthropod populations in forest ecosystems.

Oribatid mite community structure in relation to elevation and geology on the slope of Mount Kinabalu, Sabah, Malaysia

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Patterns of soil arthropod in relation to temperature and geology had been discussed between distant areas like Tropics and Temperate. These comparisons are influenced by seasonal changes and / or geographical isolation. Mt. Kinabalu is one of the very few mountains in the Asian Tropics that can reveal the real effects of temperature to soil arthropods without seasonal changes and geographical isolations. An aim of this study is to detect the patterns of oribatid communities in relation to different elevations and geographical substrates on the slopes of Mt. Kinabalu. Mt. Kinabalu is located in northern part of Borneo Island, Sabah, Malaysia. Oribatid mite communities were investigated in eight permanent plots on the slopes of Mt. Kinabalu, which form a matrix at four elevations (700, 1700, 2700 and 3100m a.s.l.) on two contrasting geological substrates (i.e. Sedimentary and Ultrabasic rocks). Oribatid mites were sampled by fifteen 100cc soil cores from the total organic layer of each plot in November 1996. Oribatid mites were extracted from the cores samples by the Tullgren funnel with 40 W light bulbs for 72 hours. Environmental variables (climate, soil characters and plant community structures) were also investigated at each plot.

The density of Oribatid mite was larger in sedimentary plots than in ultra basic plots. The density in sedimentary plots was relatively constant from 700 to 2700m, but suddenly decreased at 3100m. The density in ultrabasic soil was smaller at 2700 and 3100 m than at 700 and 1700m. Species richness was larger in sedimentary rocks than in ultrabasic. Species richness in sedimentary plots was in the same level at 700 and 1700m, and it gradually decreased from 1700 to 3100m. Species richness in ultrabasic plots gradually decreased with altitude from 700. The density and diversity of Oribatid mite decreased with altitude, but in sedimentary plots they were relatively kept at higher level than in ultra basic plots. Oribatid mite density has significant positive correlation with plant above ground biomass, organic PO₄ and negative correlation with Ca. Oribatid mite species richness has significant positive correlation with plant above ground biomass, NO₃ content, litterfall and fine root and negative correlation with altitude and Ca. Species in Galumnidae, Otocephidae, Haplozetidae and Scherolibatidae were dominant at each plot. Cluster analysis and Canonical correspondence analysis showed the importance of an elevational change for the oribatid mite community structure. In conclusion, total density or species richness of oribatid community was influenced by both of geological effect and elevational effect, and the community structure or similarity might be strongly influenced by the elevational effect.

Community succession in soil detritivorous macrofauna in a managed beech forest

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Much attention has been paid to the impact of management practices on forest biodiversity. Most studies, however, attempted to compare different management systems with little focus on successional pattern of biodiversity along silvicultural cycle. Ponge and Delhaye (1995) distinguish two phases during a natural forest cycle, i.e. an early autotrophic phase where soil decomposer communities are dominated by macro-arthropods, followed by an heterotrophic phase with communities dominated by anecic earthworms. The present study aimed at describing soil macroinvertebrates community succession along a managed forest cycle. We particularly addressed three questions: do macro-detritivore communities density and biomass change over the stand rotation? What are the factors structuring them? How vary their diversity?

Fifteen stands were chosen in the “Forêt Domaniale d'Eawy” (Normandy, France), an even-age beech monoculture (*Fagus sylvatica* L.), to represent a silvicultural cycle including five phases (29, 61, 127, 168 years-old and regeneration phase as described by Aubert *et al.*, 2003). Humus form was described and macro arthropods were sampled from soil and litter on a square meter (5 phases x 3 stands x 3 points x 2 strata = 90 samples). Earthworms, Isopoda and Diplopoda were identified to species and insects to families, counted and weighed. Fauna records were analysed with Correspondence Analysis (CA) and Hierarchical Clustering (HC). Structural (species richness, Shannon and Evenness indices), functional (FD for factorial diversity on the two first axis of CA) and compositional (within- and between-group similarity) diversities were investigated for each stand group of the empirical model (SFTS procedure and multivariate analysis).

Total density and biomass decreased with stand ageing. Nevertheless, soil and litter density and biomass presented different patterns. Furthermore, the first CA axis (18% of total variance) was related to a gradient of stand maturation and the second one (13 % of total variance) was interpreted as an anthropic perturbation gradient. Structural diversity decreased from young to old phases, while FD presented a bell curve with maximum values occurring in mature stage on the two first axes. Within group similarity showed lowest values in mature stages but inter-groups similarity allowed to separate regeneration stands from the others.

Decomposers are deeply impacted by silvicultural practices. Thickness and stratification of humus appear to strongly influence the detritivore macro arthropod community. The thickest litter (i.e. in the young dark stages without motorized interesting) hosts the more abundant communities while stratified humus (i.e. in the mature stages with open canopy) presents ecologically differentiated communities. Regeneration phases are very particular, depending on the way that the forester has solved the lack of seedling establishment. This 170-years rotation seems to be too short to include an heterotrophic phase during which natural regeneration should occur.

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Changes in soil invertebrate communities associated with pine or heather litter, during first year of decomposition

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Current plans in the Scottish Highlands seek to extend the range of native woodland dominated by Scots pine (*Pinus sylvestris*). Effects of such expansion on vertebrates and above ground invertebrates has already been investigated, but little consideration (eg Horwood and Butt, 2000) has been given to soil dwelling invertebrates.

Work described here looks specifically at the decomposition of pine litter in comparison with that of heather (*Calluna vulgaris*) at the Abernethy Forest Reserve in Scotland, an area of the largest remaining tract of native Scots pine in the UK. A range of pine regeneration sites were examined but this work focuses on comparing mature woodland with adjacent moorland, where woodland regeneration is anticipated. The two major soil types within the reserve, iron podzol and peat were both examined. Objectives were to record colonization of pine and heather litter by soil invertebrates over a period of 12 months; to note physico-chemical changes in the litter itself and to assess relationships between litter type, length of time in the field, soil type and habitat. A morphospecies technique was utilized to assist the separation of oribatid mite species.

Plastic litter bags (0.1 x 0.1 m) with mesh of 4 mm (N = 360) were provided with collected, air dried heather or pine litter. These were pinned below pine or on moorland and representative samples collected on a 3 monthly basis. From some bags invertebrates were extracted using Tullgren funnels, from others the litter material itself was analysed directly. Results were then subjected to two way indicator species analysis (TWINSPAN), detrended correspondence analysis (DECORANA) and canonical correspondence analysis (CANOCO).

Some 3,000 animals were collected of which half were oribatid mites, representing 41 morphospecies. Early collections showed some significant clustering of results by site but this diminished over time. At all sites, twice the number of invertebrates were found in heather compared with pine litter bags. Woodland litter bags contained more invertebrate groups than those from moorland sites. At peat sites similar numbers were found from both woodland and moorland whilst at podzol sites woodland bags comprised 85% of invertebrates found. Litter mass generally decreased by 40-60% over 12 months, heather initially decomposed more rapidly than pine. CANOCO showed that almost half of variance within the invertebrate community in litter bags could be explained by the macronutrient concentrations measured.

Changes in invertebrates found over time may be due to differences in feeding methods – fungal feeders followed by litter feeders and finally predators, shown e.g. by an increase in predatory mesostigmatid mites at 6 months. Collection of samples over a single, annual cycle, made it difficult to determine which changes in community composition and abundance were seasonal and which were truly successional. There appears no single species directly related to nutrient concentrations within litter and it is likely that a range of species at different trophic levels are important during decomposition within this system.

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Soil macrofauna patterns in British woodlands

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The Soil Biodiversity Programme at The Natural History Museum, London, is investigating global patterns of soil invertebrate biodiversity. This is a frequently overlooked, but critical part of any terrestrial ecosystem. By obtaining abundance and species richness estimates for key soil macrofauna functional groupings from a range of forest types, we aim to build up a picture of the soil processes potentially mediated by the soil macrofauna of the area. These data will form part of our global macrofauna study and will provide unique insights into the functional ecology of the soil biota. The study will provide baseline data regarding the soil macrofauna and focus upon termites, earthworms, ants, beetles, centipedes, millipedes, spiders and woodlice.

As part of this process we are undertaking intensive soil invertebrate surveys of a range of British woodland types. A standardised sampling method, previously used in multiple studies around the world, allows direct comparison between sites. Techniques include Winkler bag extraction of litter and surface soil for active macrofauna, and hand-sorting for earthworms. Upon identification, the various soil assemblages will be compared across the woodland types in terms of their functional composition and potential effects on soil properties.

We have now completed our first year's worth of sampling in Britain, and analysis of the data has shown interesting patterns regarding seasonality and vegetational effects. This initial work has led us to concentrate on two specific subject areas: (a) our 'flag-ship' site in the New Forest, in which we are undertaking a long-term study of seasonality, sampling monthly over 10 years; (b) investigation of differences between the woodland types as described by the National Vegetation Classification (NVC). To date, we have sampled 8 of the most important NVC dry woodland types present in southern Britain.

In this talk, Kelly Jackson will outline the methods being used for these studies and present the preliminary findings from the initial data.

An analysis of the spatial dissociation of two endogeic earthworms in the Colombian “Llanos”

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Although there has been a growing interest in the study of soil fauna spatial distribution during the past decade, the identification of the environmental driving factors behind the population patterning has been difficult to highlight. Soil physico-chemical heterogeneity is partly responsible for structuring the population. However, the available statistical analyses show that the proportion of the population spatial variance that can be ascribed to soil habitat variability is modest. This study explores the hypothesis that there are complementary effects of both soil physical variability and interspecific relationships among populations. We studied the spatial distribution of two medium-sized endogeic earthworm species (*Andiodrilus* n. sp. and *Glossodrilus* n. sp.) and the possible spatial segregation between them. The survey was undertaken in a native savanna and an introduced grass-legume pasture at the Carimagua research station (CORPOICA-CIAT) in the Colombian “Llanos”. Fieldwork was conducted in the well-drained isohyperthermic savannas of the Eastern Plains of Colombia (4° 37' N and 71° 19' W, 175 m altitude), where the climate is subhumid tropical with a dry period of four months. Sixty-four points distributed regularly in the nodes of an 8x8 grid were sampled during three consecutive years (1993-1995). The presence of spatial dependence in the data (i.e. earthworm counts) was tested using two different approaches: geostatistics and the SADIE analyses. The cross correlation between population density of both species was negative in those cross semi-variograms adjusted to the spherical type (all except one). In order to determine whether the observed patterns were transitory or durable we used the association index developed with the SADIE system. This index also allowed testing the spatial association or dissociation between earthworm counts. We obtained contrasted results depending on the land use system. The spatial organization of both species was well structured in the natural savanna while they were randomly distributed in the pasture in almost all sampling dates. When the spatial distribution was different from randomness it was always aggregated irrespective of the land-use system. There was no absolute stable spatial pattern in the natural savanna although a general pattern seemed to emerge. On the contrary, no pattern was observed in the pasture. The endogeic earthworm species displayed opposite spatial distributions ($p < 0.05$) that were of different intensity depending on the sampling date. The presence of opposite patches and gaps suggests the presence of a competitive exclusion phenomenon (at least spatial) that deserves further investigations.

The efficiency of soil hand-sorting to assess the abundance and biomass of earthworm communities. Its usefulness in population dynamics and cohort analysis studies

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Because soil is a hidden and opaque environment, many extraction methods, generally destructive have been applied to quantify and estimate earthworm numbers under field conditions. Digging and hand sorting of soil blocks is a widespread method that is used frequently in the study of earthworm communities, although it is very time consuming, tedious and even back-breaking. Since many earthworms are not extracted with this method an additional sampling of small soil blocks have been used to collect those earthworms of smaller size, but this is rarely addressed in earthworm quantification and population density may be underestimated. The objective in this study was to address the efficiency of the hand sorting method for the extraction of earthworms of different size and the usefulness in population dynamics and demographical studies. We used data collected during two years in a detailed and comprehensive study of earthworm communities conducted in the Neotropical savannas of Colombia. The study was conducted at the “Centro Nacional de Investigaciones” Carimagua (CORPOICA-CIAT) (4° 30'N, 71° 19'W and 150 m a.s.l.). Earthworms were hand sorted in two different and contrasting plots, a native *Trachypogon* sp. savanna and a 17-yr old grass-legume pasture (*Brachiaria decumbens* + *Pueraria phaseoloides*).

The performance of direct hand-sorting of soil monoliths for earthworm extraction during a considerable continuous time period resulted in fluctuations of efficiency values when compared to those from washing-sieving samples. In general, the efficiency of the hand-sorting method varied owing to the species considered and ranged from 31.4% in the case of the smallest species, i.e. Ocneroдрilidae n. sp. to 100% for the epigeic *Aymara* n. sp. in the savanna and from 44% to 80% in the pasture, for the same species. In the case of the endogeic *Glossodrilus* n. sp. values of efficiency were similar in both systems, i.e. 51.7% and 58.1%, in the savanna and pasture, respectively. By using frequency tables the average efficiency of 1m² soil cores handsorting in relation to washing-sieving techniques was calculated for each weight class. The relationship between these variables was not linear, and there was a decrease in the efficiency after a given weight. Only those data fitted to a spherical type curve, reaching a maximum or a plateau (a sill), that was different according to the species, were graphically represented. From the density of each weight class obtained with the two extraction methods a correction factor can be thus calculated for these three species and used to obtain more reliable figures of total density and biomass for each size class.

Adaptive significance of morphological modifications among oribatid mites (Acari: Oribatida) in relation to habitat differentiation

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In the forest floor of mature forests, oribatid mites are often numerically the dominant group of arthropods (Wallwork 1983). Many oribatid mites, however, occur not only on the forest floor but also in arboreal and littoral environments (e.g. Luxton 1992; Behan-Pelletier & Walter 2000). Therefore, it is most likely that oribatid mites specialized to arboreal and littoral environments have developed morphological modifications and have evolved in accordance with aspects of the architecture and/or microclimate in such environments.

Mangrove forests cover a wide range of coastal areas in tropical and subtropical regions. Unlike in other terrestrial forests, the forest floor and bases of the mangrove trunks are flooded regularly. We have found five specific microhabitats (canopy, trunk, flooded trunk, littoral algae, and forest-floor soil) for oribatid mites in mangrove and bank forests in the Ryukyu Islands, southwest of Japan, and have examined the adaptive significance of morphological modifications among oribatid species in those microhabitats.

A total of 96 oribatid species were recorded from canopy (leaves and branches), bark of flooded trunks (trunks of 0-50 cm high and knee roots), bark of trunks higher than 50 cm, and littoral algae in mangrove forests, and from the forest-floor soil in an adjacent bank forest. There were no significant differences in body length, body width, or notogastral length among oribatid species from the five microhabitats. The mean sensillus length of the oribatid species from the forest-floor soil was about twice that of species from the other microhabitats. The mean claw length was larger in the oribatid species from the flooded trunks and littoral algae than in those from the other microhabitats. In the canopy and trunks, the proportion of tridactyl species was larger than that of monodactyl species (tridactyl species occupied ca. 80% in the canopy and ca. 60% on the trunks). The proportion of tridactyl species in the forest-floor soil accounted for only about 20%, but both types of species had short claws. On the other hand, the oribatid species from the flooded trunks and littoral algae were predominated by monodactyl species with a longer claw (monodactyl species occupied 100% in the flooded trunk and more than 90 % in the littoral algae), which implies a consequence of selection for regular tidal flooding.

These modifications in claw morphology of oribatid mites could be interpreted as adaptations to a difference in the predictability of the environmental conditions of microhabitats in mangrove forests.

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Soils in transition: above- and belowground development

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Restoration of former agricultural fields towards more natural and species rich ecosystems is one of the major land conversion activities in industrialised countries. During the transition from a high-input system towards a more stable, low-input system, a gradual shift from bacterial to fungal dominated decomposition is expected. Theory also predicts longer food chains and increased food web complexity, which will influence density and diversity of root herbivores and pathogens. However, the mutual interactions of soil organisms and their impact on successional shifts in vegetation are rather unexplored. With respect to successful restoration, many uncertainties on the role of soil organisms in processes, such as decomposition and rate of nutrient turnover, still remain. To investigate above- and belowground changes during this type of secondary succession, the development of microbes (bacteria, fungi), soil nematode community as well as vegetation composition was tested in a chronosequence study. Preliminary results show that, in addition to chemical and microbial parameters, soil nematodes significantly contribute to the amount of explained variability in vegetation composition. The effect of management strategies (such as top soil removal, hay spreading, soil spreading or introducing organic substrates) on changes in above- and belowground subsystems is studied in field experiments in order to develop practical applications for enhancing the process of secondary succession. To test the effect of soil biota composition on the competition between plant species and on the plant-soil feedback response of such a community - hypothetical leading to successional shifts in vegetation composition - a mesocosm greenhouse experiment is set-up. For this experiment, twelve plant species, representing three different stages of secondary grassland succession, are grown in mixed communities on ex-arable soil originating from the 'chronosequence sites'.

The structure diversity of soil invertebrates in the Pechora river basin

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The problem of an estimation of biological diversity is one of the basic moments of establishment of soil zoology as science. At present time the actuality of this problem grows, that explained heightened management of people on the natural ecosystems. The Pechora river basin was elected for study of structure diversity of soil invertebrate animals. Researches of soil invertebrates on this territory were not spent or they had fragmentary character. The territory of the Pechora river basin is also unique because it consists of lands with intensive anthropogenous loading (oil and gas pipelines, forest clear cuttings), and especially protected territories (Pechoro-Ilych, Synja, Ustj-Unja reserves of flora and fauna). The standard soil-zoological methods and landscape, geobotanic descriptions were applied. It allows to reveal the changes of structure diversity of soil invertebrates in plant and soil cover of researched area. In total 2400 soil-litter samples have been selected during the summer period of 2002-2003 years in nine types of vegetative formations: pine, spruce/fir, aspen, birch, willow and mixed forests, mountain tundra, fens and bogs, grasslands, which are widespread in the middle and northern taiga. Such parameters of structure diversity of soil invertebrates as taxonomic composition and a relative abundance, a ratio of trophic groups and dominant species were determined. Soils of taiga zone are characterized by less diversity of invertebrates in comparison with southern regions. In the northern soils some taxonomic groups of saprophage invertebrates as Diplopoda and Isopoda are absence. The role of some taxonomic groups (Lumbricidae) is decreased. But earthworms keep their number and biomass in biocoenosis with well advanced soil structure, thin litter and favorable hydrothermal mode. Diptera larvae inhabit drainage soils in deciduous forests. The abundant group of predatory invertebrates is Lithobiidae. Their distribution is not depend on soil and plant type, so they are numerous everywhere. Rove-beetles is taxonomically and ecologically reach group of predatory invertebrates dwelling in terrestrial ecosystems. Ground beetles, weevils, click beetles are common representatives of different soil type. The continuous homogeneous cover from mosses in taiga zone makes constant inhabit conditions and reduces quantity of ecological niches. It promotes to reduction of ground beetles diversity. The level and type of humidifying influences on their composition and abundance too. The same taxonomic groups are prepotent in soils of taiga biocoenosis of Euroasia. The soil invertebrate communities are characterized by polidominant structure on family, genera and specific levels. This is a typical feature of structure diversity of soil invertebrates in adjusting territories of Kola Peninsula and Siberia too. Dominant, subdominant, common, rare and single species are met in each community. Such structure is described by log-normal distribution. Parameters of a relative abundance allow to approve, that bogs with a specific hydrological mode are occupied invertebrates to in less degree. Their diversity is rather increased in pine, spruce/fir, deciduous, mixed forests. Meadows are characterized by high parameters of abundance. Changes on anthropogenous territories are revealed in decreasing or increasing of structure diversity of invertebrates. The direction of process depends on character and a degree of anthropogenous loading and explained by changing conditions of surrounding vegetation and soils. This work was done within the framework of international project “Pechora River Integrated System Management (PRISM)”

Soil fauna of floodplain forests on the European North-East of Russia

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Decomposition of leave litter in terrestrial ecosystems and formation of organogenic horizons in soils of forest communities are closely connected to live ability of soil micro- and macro- invertebrates. Floodplain forests of the European North-East, their soil cover, and, especially, soil micro- and macro- invertebrates are rather poorly investigated in this respect. The purpose of the given work consists in revealing of ecological and functional connection between alluvial soils, formed under flat of floodplain forests in taiga zone, and a biodiversity, changes of number and structure of the soil invertebrates complex.

The forest located in the central part of the floodplane terrace of a Sysola river valley (Komi Republic, middle taiga) was an object of our research. The key plots essentially differing on ecological conditions (duration of flooding by freshet waters, depth of subsoil waters, type of soil, etc.) have been allocated in this territory. These plots form a natural ecological line on a degree of increase of soil humidity: FP1 (top of mane) FP2 (the leveled plot of floodplane) FP3 (downturn between manes). Standard methods of soil-zoological researches were used for studying of micro- and macro- invertebrates, participating in transformation of litter formed on a surface of alluvial soils in floodplain forests of taiga zone. The selection of soil samples by size of 0.0625 m² and 0.0001 m² on all depth of a forest litter (4-5 sm) was carried out in 10-fold frequency monthly during the summer-autumnal period of 2003.

As the carried out researches have shown, number and a specific diversity of soil invertebrates have the strongly pronounced seasonal dynamics caused by a hydrothermal mode of alluvial soils. The most numerous group of sapropagous invertebrates, occupying forest litter, is springtails (Collembola). Their number in investigated communities varies from 3000 up to 21000 ind./m². Optimum conditions for springtails live ability develop in soils, formed under flat of floodplain deciduous forests at tops of manes (FP1). Soils of the given habitats, due to deep subsoil waters, are well aerated in all terms of the vegetative period. Two peaks of springtails number – in June (20270 ind./m²) and in September (18040 ind./m²), are marked in these habitats. Their number is characterized by practically two-multiple reduction (7967 ind./m²) during the maximal warming up and aridity of soil in July. In more damp habitats (FP2 and FP3) gradual rise of springtails number by August (accordingly 8380 and 20760 ind./m²) with subsequent its sharp decrease during the autumn period (accordingly 4200 and 3340 ind./m²) is observed. Researches have shown, that highly specialized springtails species are absence in soils of floodplain forests. Widespread species, the majority from which are typical hygrophilous representatives usually makes a basis of soil invertebrate complex.

Total number of large invertebrates in forest litter of alluvial soils closely correlates with humidity of soil (the factor of correlation for FP1, FP2, FP3 makes accordingly -0.97, -0.68, -0.72) and will gradually increase by the end of the vegetative period, except the plot FP1 where peak of total number falls at August. The specific structure of complex of soil large invertebrates is most various and thus is most stable on terms of selection in litter of plot FP2. Soil on this plot borrows intermediate position on a degree of humidifying between soils of plots FP1 and FP3. In all terms of selection earthworms (Lumbricidae) and centipids (Lithobiidae) prevailed here, and by the end of the vegetative period number of representatives from spiders (Aranei) and beetles (Coleoptera) has increased. In litter of "dry" habitats (FP1) the taxonomic structure and dominating groups of large invertebrates essentially varied on terms of selection. The ants were practically a constant component of complex of soil large invertebrates on this plot. They were absent in all terms of selection in soils of plots FP2 and FP3). Earthworms have been allocated only in August samples, in the same term the rove beetles (Staphylinidae) dominated here too. The litter of dump habitat (FP3) was characterized by the least diversity of large invertebrates. The reduction of the level of subsoil waters by the end of the summer period and, accordingly, decrease of humidity of the top soils horizons, and the receipt of fresh leave litter have caused significant expansion of invertebrates in alluvial soils occupying downturn between manes during the autumn period.

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The soil Microarthropods spread with birds in Arctic and Antarctic Islands

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Our studies performed in 1997-2003 demonstrated the existence of a previously unknown factor of microarthropod distribution, namely, their spread by birds. Various groups of soil mites (Oribatei, Gamasida, Acaridia, Trombidiformes, and Prostigmata), as well as Collembola and larvae of Diptera, Staphylinidae, etc., are almost always present in the feathers of various birds. When examining 3100 bodies of birds from 170 species, we founde alive Oribatei and Collembola reproduce in bird feathers. The spread of these arthropods by birds may be the main factor of their biogeography, especially in the Arctic, on islands, and in desert oases. Soil microarthropods could have spread across the vast areas of water and ice of the Arctic Ocean, which are usually insurmountable obstacles for the distribution of organisms with the low mobility characteristic of these species, to islands remote from continents only if an additional potent factor has facilitated their distribution. Birds, which can travel over thousands of kilometers between islands and continents, are a probable factor of this type. Our finding that Oribatei live in bird feathers clarifies many questions on the biogeography of Oribatei and other soil microarthropods, as well as the mechanism of their spread to Arctic and Antarctic islands.

Oribatei were constantly found in the feathers of birds belonging to various taxonomic and ecological groups. Many of them reproduced there; this was demonstrated for *Hypochthonicus rufulus*, *T. velatus*, *S. laevigatus*, *Palaeacarus hystricinus*, *T. tetrorum*, *Nothrus palustris*, *P. peltifer*, *Camasia borealis*, *C. spinifer*, *N. coronata*, *Eremaeus oblongus*, *H. reticulata*, *C. areolatus*, *P. punctata*, *Diapterobates notatus*.

The alive oribatid mites have been collected in birds feathers in Arctic islands (Novaya Zemlja, Wrangel, Vajgach, on the Barents sea coast) and in some subantarctic islands.

Microarthropods in the nests and feather of birds in the Moscow region

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In 1983-2004 in Moscow region we observed more than 2000 birds (*Columba livia*, *Parus major*, *Luscinia svecica*, *Passer domesticus*, *Passer montanus*, *Corvus frugilegius*, *Corvus monedula*, *Corvus cornix*) and more than 200 nests of those species. Following groups of microarthropods were recorded: Diplopoda, Acari, Aranea, Collembola, Thysanura, Dermaptera, Psocoptera, Mallophaga, Homoptera, Hemiptera, Thysanoptera, Coleoptera, Lepidoptera, Hymenoptera, Siphonoptera, Diptera.

**Oribatei in the nests and feather of Bluethroat
(*Luscinia svecica*, Turdidae, Aves) in European Russia**

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In 1999-2003 in Moscow region we observed 10 nests and 8 feathers of Bluethroat (*Luscinia svecica*). The following species as recorded; *Achipteria coleoptrata*, *Belba* sp., *Camasia*, *Carabodes marginatus*, *Cepheus cepheiformes*, *Chamobates lapidarius*, *Damaeidae*, *Diapterobates notatus*, *Eremaeus oblongus*, *Hermannia reticulata*, *Hypochthonius rufulus*, *Liochthius sellnicki*, *Liochthonius* sp., *Minithoretetes pseudofusiger*, *Oppia minus*, *Oppiella nova*, *Phthyracarus borealis*, *Phthyracarus ligneus*, *Phthyracarus* sp., *Punctoribates punctum*, *Schelorbates laevigatus*, *Scutoventrix minutus*, *Sphaerobates gratus*, *Suctobelba trigona*, *Suctobelba* sp., *Tectocephus velatus*, *Trichoribatus trimaculatus*, *Zygoribatula exilis*.

MACROFAUNA version 2.0 - a database management system for assessing the soil fauna diversity of natural and disturbed ecosystems

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The MACROFAUNA database is the result, in a first time, of a pioneer version written and developed in Dbase IVTM by Carlos Fragoso at the beginning of the 1990's and, in a second time, of a consultation between all participants of the two International Biodiversity Observation Year (IBOY) workshops held in Bondy (France) in June 2000 and december 2001. The major interest of the MACROFAUNA database is that it will constitute a considerable sum of data which can be used as basic tool as for numerous of fundamental questions than for applied researches. Main objectives are : 1- to assess the soil macrofauna biodiversity at different geographic scales, from local to regional. 2 – to assess the influence of land use, biota perturbation or specific environmental factors on soil macrofauna. 3 – to assess the influence of soil macrofauna communities modifications on soil properties and 4 – to research bioindicators associated with specific environmental parameters or soil perturbations.

All data are collected on the basis of the sampling pattern as defined by the Tropical Soil Biology and Fertility (TSBF) protocole : a site is represented by a transect or a quadrat and identical soil monolithes are carried out at regular intervals. Each monolithe is divided in regular strata. MACROFAUNA database contains at present data for 843 sites and 7486 samples, distributed over 37 countries through the world (Europe : 42 sites and 557 samples ; North America : 12 sites and 144 samples ; Central and South America : 460 sites and 4006 samples ; Africa : 216 sites and 1960 samples ; and Asia/Oceania : 113 sites and 819 samples).

MACROFAUNA V2.0 was written in Microsoft Access and contains 155 variables distributed among 5 distinct groups: 3 are linked to the different levels of precision of field sampling (sites, soil samples and strata) with 123 environmental and biological variables and the two others, to the taxonomical aspect of the sampled fauna and to the bibliographical references in which results were published. Because of the great number of variables and to make data input and extraction easier, the database was divided in two distinct interfaces : the “ data input interface ”, an interface in which data are distributed in 5 “one-to-several” related tables corresponding to the 5 variables groups, and the “ data extraction interface ”, in which all data are brought together in the same table. Search and extraction of data can be executed via keywords and an advanced search can be executed by way of a combinaison of keywords with the help of classical Boolean operators. The result of a query appears in tabular form and can be directly exported under numerous formats (txt, rtf, ASCII, Microsoft Excel...).

A preliminary result of the data analysis underlines a soil fauna total density significantly higher in the tropical areas compared to temperates ones because of a great abundance of termites and ants, and a soil fauna total biomass significantly higher in the temperate areas because of a greater abundance of earthworms.

A new giant earthworm species (*Oligochaeta*, *Glossoscolecidae*) for the Guayana shield

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The Guayana shield, including East of Venezuela, Guyana, Suriname, French Guiana and the North of the Brazilian states of Roraima and Amapa is considered to be both an important refuge zone and a great centre of endemism. The earthworm fauna of this area is still largely unknown and only 19 species have been listed so far from French Guiana. We describe here a giant epigeic earthworm from French Guiana, *Rhinodrilus saülensis* nov. sp. (*Oligochaeta*, *Glossoscolecidae*). This genus is characterized notably by the presence of three pairs of calciferous glands in the segments VII-IX. The new species is externally distinguished by a length of 80 to 120 cm in average extension, a punctuated coloration on the dorsal face of the body and an irregular array of the postclitellar setae. The clitellum 15 segments long extends over segments XV to XXIX and tubercula pubertatis are in XXIII-1/2 XXVIII. Male pores are intraclitellar at segment XXV. As regards internal morphology, the species is holandric, with two pairs of seminal vesicles. The posterior pair is long and reaches segment XIX. They have three pairs of spermathecae in VII-XIX and two pairs of lateral hearts in X and XVI. There is one pair of holonephridia per segment. This species, particularly because of the tubular structure of the calciferous glands, is close to *R. garbei* Michaelsen, 1926, described from South of Brazil, but distinct in particular because of the size of the second pair of seminal vesicles, the coloration and the arrangement of the setae. The name of the new species comes from the village of Saül, in the centre of French Guiana, where this earthworm was found.

Importance of hydro-morphological factors within the life cycle of riparian ground beetles (Coleoptera: Carabidae)

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Natural and natural-like riverbanks are extremely unstable and dynamic habitats whose colonisation make high demands on soil animals. Species have to deal with changing water levels and the resultant morphological processes. Due to their sensitivity to environmental changes, carabid beetles are proved to be suitable ecological indicators in riparian habitats. The high variety of microhabitat structures at riverbanks is very well characterised by the species distribution patterns. However, most habitat analysis account only the adults, although the hemiedaphic sensitive larval stages are expected to be the key factor in habitat selection (cf. Lovei & Sunderland 1996). Thus, we were interested in adaptations on hydro-morphological processes within the life cycle of riparian ground beetles.

Our investigation was carried out from 2000 to 2003 at the riverbanks of the potamal section of the River Elbe (Saxony-Anhalt, Germany). Beetles were sampled by means of pitfall traps in late spring, below lower mean water level. The traps were installed both at open soil habitats close to the water line and in different vegetation structures. To analyse the key factors governing the distribution of the species, several environmental parameters were surveyed at every single trap.

Especially in semi-terrestrial habitats the specie-rich assemblages clearly reflected differences in grain size. We focussed on stenotopic, riparian beetles with larvae running temporarily on the surface such as *Bembidion velox*. According to Bräunicke and Trautner (1999) this species has become rare in Germany since the dynamics of large rivers were reduced by water management. Thus the species should be highly specialised. Multivariate analysis showed, that *B. velox* is strongly adapted on sandy open soil habitats near the water line. Both, imagines and larvae, were only found in these habitats. Complementary laboratory experiments clarified, that especially the mortality rates of the small first instar larvae were significantly higher in substrates of less grain size. Due to its low cruising radius the oviposition site is important for larvae development. As further experiments pointed out the eggs are inured to inundation. This is advantageous in semi-terrestrial habitats as well as the short developmental periods.

All in all we could show by multivariate analysis of field data and complementary laboratory experiments that the riparian ground beetle *B. velox* is adapted within its life cycle to hydro-morphological dynamics.

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Colonization of beech forest soils of different humus types by autochthonous and allochthonous soil mites (Acari)

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In a field experiment we studied the importance of abiotic and biotic factors for the abundance of soil microarthropods (especially oribatid mites) in soil from a moder beech forest (Solling) and in soil from a mull beech forest (Göttinger Wald). From each of the forests we sampled a small soil column (5 cm Ø) and incorporated it into the center of a larger soil column from the other forest (20 cm Ø). As a control we established inner and outer columns which were both from the same forest. Before the experiment half of the inner columns were defaunated, the other remained non-defaunated. After seven month the inner columns were sampled.

Hypochthonius rufulus, *Eniochthonius minutissimus* (Oribatida) and Prostigmata were more abundant in the non-defaunated than in the defaunated soil columns suggesting that these animals are slow colonizers. In contrast, Gamasina, Uropodina, Astigmata, *Tectocephus velatus* (Oribatida) and *Suctobelba trigona* (Oribatida) had higher abundances in defaunated soil indicating that they are fast colonizers of early successional stages in soil. Fast colonizers were characterized by short reproduction times, parthenogenesis and high mobility. Desmonomata, Chamobatidae, Brachychthonidae and Oppiidae (all Oribatida) mainly colonized autochthonous soil columns. Their densities in the field therefore are probably limited by abiotic conditions. In contrast, Ptyctima and Hypochthoniidae (both Oribatida) colonized autochthonous and allochthonous soil indicating that these animals are not limited by abiotic factors in the field but by biotic interactions, e.g. competition.

Results of our study indicate that both abiotic and biotic factors are important for the structure of the soil animal communities in forest ecosystems.

Spatial and compositional patterns of earthworm associations on a chalky slope of the Seine valley

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The chalky slopes of the Seine valley are characterised by highly active humus forms and by processes of secondary post-pastoral successions occurring mainly since the 50's decade. In this study, we sampled different stages using a Space For Time Substitution procedure, in order to test the hypotheses that (i) earthworm associations are less original in the stable stages of the succession gradient and (ii) the strength of the spatial patterns of assemblages is stronger in stable stages. A spatially explicit sampling design of 262 points was used. Factorial diversity was computed on a correspondence analysis (CA) of earthworm densities of the whole data set. Further CA were computed on earthworm densities in each stage and the coordinates on the first axis were used to compute semivariograms. Factorial diversity was slightly different between stages, and spatial patterns of earthworm associations on early stages were stronger in stable stages than in dynamic ones. This allows to conclude that (i) in the context of the chalky slopes the time scale allowing spatial structuration of earthworm assemblages is in the order of the decade and (ii) that coexistence mechanisms driving earthworm associations seem to differ within the succession, with equilibrium mechanisms in the stable stages and non-equilibrium in the dynamic ones.

Spatio-temporal small scale study of earthworm associations on a chalky slope of the Seine Valley

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In this study, we describe the spatio-temporal patterns recognised in a 18x18m area of physiologically homogeneous *Brachypodium* tall grassland with *Rosa* encroachment, which has been abandoned since the end of the second world war and is pastured with sheep since 1997 for conservative purposes.

The sampling scheme was a square grid of 10x10 points of 2 m mesh size. On each point, a square of 25 x 25 cm was delimited, the litter and the vegetation were removed and carefully hand sorted. The soil was dug up to the chalk (ca 25-30 cm), and earthworms and cocoons were hand sorted and fixed in 4% formaldehyde.

At each of the five sampling dates from October 2000 to November 2002, each point was displaced in a clockwise sense, in order to sample in an undisturbed area. These modifications in xy coordinates were considered as negligible. Earthworm populations were dominated by endogeics, mainly by *Allolobophora chlorotica*, *Aporrectodea caliginosa* and *Allolobophora icterica*.

Results were analysed using a specific multivariate tool (PTA, partial triadic analysis, which allows to detect either the common patterns exhibited by the different sampling dates, either the deviations from this common pattern), and SADIE software, which provides a metric that allows to compare the strength of the spatial patterns between species and dates.

Despite ephemeral patterns for most species, some of them exhibited relatively strong and constant spatial patterns, mainly *A. chlorotica* and *A. caliginosa*. SADIE analysis provides a mean to describe stability and to quantify displacement of patches and gaps for some species. Results are discussed with a comparison with those found at larger scale.

Small scale patterns of earthworms associations on a chalky slope of the Seine valley

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Most of the studies on spatial patterns of earthworm associations are driven at a scale of some tenth of meters, with a spatially explicit sampling with a mesh size of ca 2 to 4 meters. Often analysed using geostatistical tools, they exhibit more or less important nugget variance, which is the part of semivariance, often dedicated to sampling error and/or spatial structure existing at a too small scale to be sampled in the grid. In the particular context of the chalky slopes of the Seine valley, we tried to describe on a single sampling date the small scale spatial patterns exhibited by earthworms species, using juxtaposed points.

Samples were taken in a *Brachypodium* tall grassland, a relatively stable successional stage. In October 2004, 64 sampling points of 25 x 25 cm were delimited in a 2 x 2 m square. After removal and carefully hand sorting of the vegetation and litter, each point was dug until the chalk is reached, hand sorted, and earthworm individuals were fixed in 4% formalin. Individuals were identified to species level, and separated into juveniles, subadults and adults. Mean density was of 164 ind. m⁻², mean biomass was of 48.15 g fw. m⁻², both dominated by endogeic species, mainly *Allolobophora chlorotica*.

Densities were analysed thanks to geostatistical and multivariate tools and SADIE analysis.

Earthworms did not exhibit strong spatial patterns at this scale for most species, except for some endogeic species, but some species show significant clustering SADIE index. These results are discussed in the light of other small scale studies of the literature. The hypothesis of a nugget variance mainly explained by a sampling error is discussed.

Earthworm population dynamics on a chalky slope of the Seine Valley: a two-years survey

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Chalky slopes of the Seine valley are characterised by relatively xerophytic microclimatic conditions compared to mean regional climate, and by a thermophile influence due to the south-facing position of some slopes. Consequently, these slopes have a conservational interest due to the presence of some plants or insect which are at the northern limit of their distribution area. Most of these organisms are infested to vegetal formations (short grasslands) that were formerly maintained by agropastoral activities, mainly sheep grazing. Since the end of the second world war, these activities have disappeared and a process of secondary succession occurs on the chalky slopes, thus threatening these populations that are not competitive in the context of *Brachypodium pinnatum* tall grassland or tall grassland with *Rosa* encroachment, succession stages leading to maple wood, the climatic formation on the chalky slopes. Vegetation processes on these slopes were described with multivariate tools leading to a statistical model describing two main trajectories from the short grasslands to maple wood: the first trajectory drives directly in a few decades to maple wood, without any successional stable stage in-between. The second trajectory comprises a stage of tall grassland dominated by *Brachypodium pinnatum*. This very stable stage can remain for at least five decades, and is quite species poor.

Earthworm populations show relatively high densities in these stages, ranging from 65 to 240 ind. m⁻². Dominated in each stage by endogeic earthworms, they exhibit contrasting patterns of density in anecics and epigeics. To describe the temporal evolution of the earthworm community, a two-years survey has been driven on two stages of the succession between November 2000 and November 2002: tall grassland and maple-hazel wood. Each month, a set of 5 replicates of 0.5 x 0.5 meters was randomly chosen in a 60*48 m physiologically homogeneous area, with a minimum distance between samples of 12 m, in order to avoid the main part of spatial autocorrelation between replicates. Each sampling point was then hand sorted until the chalk is reached, deep which was ranging between 20 and 30 cm. Earthworms and cocoons were fixed in 4% formalin, identified to species level when possible, individually counted and measured in the laboratory, and classified into adults, subadults and juveniles. Above- and belowground vegetal biomasses were also gathered and quantified after drying in the lab. The accuracy of hand-sorting was checked, and if necessary corrected with the results of wet-sieving of four 6cm-diameter cores sampled per plot.

Results exhibit variations in the species assemblages both within and between the two stages.

Differences between the two formations in term of specific composition are limited to endogeic species: *Allolobophora chlorotica* is dominant in both formations, but *Aporrectodea caliginosa* and *Aporrectodea icteria* strongly decrease in the maple wood. *Murchieonia minuscula* reaches high densities in the maple wood.

Differences also occur between species for their period of inactivity (and its length) during the summer drought period. Differences in the period of sexual maturity are also noticed and discussed. Results are discussed in the light of other results obtained on the same site and other chalky slopes of the Seine valley.

Long-term changes in pine forest soil mesofauna: correlations with temperatures and soil moisture

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Long-term (1992-2002) changes in numbers and species richness of soil gamasina mites, collembola and enchytraeids have been investigated on the background of fluctuations of climatic factors and soil moisture within three sampling plots located in young (30-40 years) middle-aged (50-70 years) and old (150-200 years) Scotch pine forest in North Vidzeme Biosphere Reserve, Latvia.

Sampling of soil microarthropods and enchytraeids (only since 1994) was performed once a year, in late August. One hundred soil cores (5 cm² x 10 cm) were taken within each sampling plot every year. Soil microarthropods were extracted from the cores by using modified high gradient extractor. Enchytraeids were extracted by using wet funnel techniques from 30 soil samples (23 cm² x 10 cm). Soil moisture was determined as water content in the organic horizon O by weighting and drying at 105° C ten randomly taken soil samples.

The highest average numbers of soil fauna have been recorded in old pine stand: springtails about 8300 ind/m², gamasina mites - 3200 ind/m², and enchytraeids - 10 700 ind./m². These groups had also the highest species richness in the old forest (collembola 56 species, gamasina mites 34 species). Enchytraeids were represented mostly by two dominants *Cognettia sphagnetorum* and *Achaeta spp.* in some cases comprising 95 per cent of total numbers of worms. Species richness of enchytraeids was relatively low – 7 species in young and middle-aged forest and 6 species in old forest. The lowest average numbers of invertebrates have been recorded in the middle-aged forest: collembola about 7300 ind/m², 55 species, and gamasina mites - 3100 ind/m², 25 species. Enchytraeids showed the lowest average abundance (8300 ind./m²) in the young pine stand. The lowest species richness of collembola was recorded in the young forest (47).

Collembola showed a decrease in numbers and species richness during the sampling period. However, these trends were statistically significant (P=0.05) only in the old stand (both, for numbers and species richness) and in the young and middle-aged forest (only for species richness). Species richness and numbers of collembola were positively correlated with soil moisture (respectively, r=0.68 and r=0.72, P=0.05) in the middle-aged pine stand.

Gamasina mites showed statistically significant decrease (P=0.01) only in species richness in the young and middle-aged pine forest. No statistically significant correlations with the soil moisture were found.

Numbers of enchytraeids were highly fluctuating during 1994-2002. Statistically significant correlations with soil moisture were recorded for total numbers of worms (R=0.73, P=0.05) and *C. sphagnetorum* (R=0.75, P=0.05) in the middle-aged pine stand and for species *Mesenchytraeus pelicensis* in the old (R=0.66, P=0.05) and young (R=0.74, P=0.05) pine stand.

No statistically significant trends in mean January-August air temperatures were found during the period of investigations and correlations between temperature and community characteristics of soil animals were not statistically significant.

Effects of disturbance on the biodiversity of isopods in temperate grasslands

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Connell's intermediate disturbance hypothesis was tested on a simple community of isopods in grasslands. Disturbance in these grasslands is primarily caused by rabbit grazing. On lightly grazed and very heavily grazed sites the diversity and equitability of the community were similar. Diversity was lowest when effects of disturbance were intermediate. Reasons for the disparity between observations and predictions are explored. We conclude that the results are better explained by Huston's dynamic equilibrium model than by the intermediate disturbance model.

Occurrence and Habitat Preference of Earthworms of Benghazi, Libya

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Field studies were conducted during February-March, 2002, to know the occurrence and habitat preference of earthworms of Benghazi, a coastal Mediterranean city in Libya, North Africa. A total of three peregrine species were recorded : *Allolobophora caliginosa trapezoides*, *Allolobophora rosea* (Family : Lumbricidae) and *Microscolex dubius* (Family : Microscolecidae). Their distribution and density in six habitats viz. vegetable garden, flower garden, green house, farmland, grassland and plain barren landscape were studied in relation to some of the physico-chemical parameters and composition of soil. *A. caliginosa trapezoides* was found to be ubiquitous and was present in all habitats. *A. rosea* was sampled from vegetable garden, green house, farmland and grassland and *M. dubius* from green house farmland and grassland. Farm land recorded the highest (230/m²) and plain barren landscape the lowest (30/m²) density of earthworms. A modest correlation ($r_s = 0.62$, $p > 0.05$) between soil temperature and density of earthworms and a very weak inverse correlation ($r_s = -0.09$; $p > 0.05$) between soil water content and density of earthworms were evident. The pH of the soil of habitats ranged from 7.1 to 7.7. Soil having more than 4.5% organic matter recorded more worms than the soil having lesser than this percentage. The soils of the habitats except that of plain barren landscape were loamy sand, whereas the soil of the latter was silt clay. In conclusion, the different habitats of Benghazi were colonized by peregrine temperate worms. The climate and edaphic conditions of the region were more suitable for these worms to settle than the tropical and sub-tropical worms found in sub-Saharan African countries.

Molecular taxonomy of earthworms of the genus *Eisenia* (Oligochaeta, Lumbricidae) using 16S rDNA and cytochrome C oxidase sequences

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The genus *Eisenia* includes several earthworm species living in decaying organic remnants, such as farm manure, barks of felled trees, litter, or different composts. Due to their prolific breeding (more than one egg in the cocoon) and the feeding habit with a large range of organic remnants, these earthworms are widely used in vermicomposting and vermiculture under the commercial name of manure-worms.

Till now, over 30 *Eisenia* species have been described, some of them widely distributed. Mostly used in composting and vermiculture are *Eisenia fetida* (Savigny, 1826) and *E. andrei* (Bouché, 1972), while *Eisenia eiseni* (Levinsen, 1884), *E. lucens* (Waga, 1857) and *E. spelea* (Rosa, 1901) are decomposers of organic matters in natural forests and guano.

The systematic status of these closely related and very similar species is often confuse and erroneous due to the high variability and often overlapping of morphologic taxonomic characters. In fact, *Eisenia fetida* and *E. andrei* are considered either species or subspecies, but it is possible to be a single taxon as well. In the same way, *Eisenia lucens* seems to differ from *E. spelea* only by its bioluminescence.

This work presents an attempt to clarify the systematic status of some of the most common *Eisenia* species, namely *Eisenia fetida*, *E. andrei*, *E. eiseni* and *E. lucens*, by means of molecular structure of rDNA. Material was sampled in Spain, Romania and Hungary in composts and natural ecosystems.

Partial sequences for 16s rDNA and for cytochrome *c* oxidase subunit I (COI) for the studied taxa were obtained. Variability of molecular structures is estimated at geographic and local populations level.

Maximum likelihood and parsimony trees show the relatedness of the four *Eisenia* taxa, the level of taxonomic distance and the convenient discrimination among them.

Does pitfall trap size influence the efficiency of epigeal Collembola?

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Pitfall traps are widely used in ecological studies. However, their efficiency depends on the density and activity of the individual species and the vegetation resistance. Trap size is not standardised for sampling epigeal Collembola and varies between 1 and 10 cm diameter. Therefore, results cannot be compared among studies.

I compared the catchability of differently sized pitfall traps (1cm, 2cm, 3cm, 4cm, 5cm, 7cm and 10cm) for epigeal Collembola. Body size of each species was measured and correlated to trap size. I postulate the existence of a minimum trap size that captures all size classes of Collembola. This trap size is proposed for maximising sampling efficiency.

Diversity and nest density of non-leafcutting, fungus growing ants (Formicidae, Myrmicinae, *Attini*) in an Amazonian rainforest and an agroforestry system

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As part of the research project SHIFT ENV 52-2 the influence of soil macro fauna on decomposition and nutrient cycles in agroforestry systems was studied and compared to a *terra firme* rainforest. Here we present the first data about species richness and nest density of those fungus growing ant species of the tribe *Attini* that do not forage on leaf of living plants, but use dead plant and other material from the litter stratum as substrate for their fungus gardens.

The field research took place at the experimental field sites of the EMBRAPA-Amazônia Ocidental near Manaus, Brazil. For monitoring diversity and nest density we investigated eight plots of 12.5 sqm each, in a primary rain forest and the same number of plots of the same size in a nearby agroforestry system of 19 ha. In all plots the lower vegetation was cut off and the soil was carefully cleaned from leaf litter. All ant nest entrances discovered were marked. Furthermore all foraging ant individuals found in the study plots were observed until they reached their nest entrance. We observed and mapped each plot for 20 hours to maximise the chance to encounter any nest entrance of *Attini* ants occurring.

All together we identified a total of 293 nests of 26 ant species from 7 genera of the tribe *Attini*. From these 26 species 22 species occurred exclusively in the rain forest and 3 species were found only in the agroforestry area. Habitat specification of the species was nearly perfect, with only a single *Cyphomyrmex* species encountered in both habitats (but with a single nest in the agroforest). Nest density in the primary forest was significantly lower (0.65 nests/sqm) than in the agroforestry system (2.28 nests/sqm) (Mann-Whitney-Test: df:1; p<0,001).

With 170 nests (74,6 % of the total nest count) the species *Mycocepurus smithi* dominated in the agroforestry system, followed by *Trachymyrmex relictus* (13,6%) and *M. goeldii* (11,4 %). The nest/species ratio was 57. In the primary forest 18 species (78%) were registered only with one, two or three nests, and the most frequent (*Cyphomyrmex* sp.) with just 13 nests, resulting in a low nest/species ratio of 2,8 for this habitat.

Thus, in the agroforestry system we found a significantly reduced species richness, but high nest densities of three species (86% of them were *Mycocepurus smithi* and *M. goeldii*). Obviously these species cope very well with the changing conditions they are exposed to in an anthropogenic influenced habitat and may play an important ecological role in soil physics and chemistry of Amazonian agroforestry systems through their subterranean digging and fungus growing activity.

Etude comparative de l'Entomofaune de deux palmeraies: l'une moderne et l'autre traditionnelle dans la region d'Ain Ben Noui (Wilaya Biskra)

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L'étude entomofaunistique est réalisée durant une année dans deux palmeraies : l'une moderne et l'autre traditionnelle à l'Institut Technique et de Développement Agricole Saharienne dans la région d' d'Ain Ben Noui (Wilaya Biskra), situées dans l'étage bioclimatique saharien à hiver doux.

Nous présentons au cours de notre étude un recensement de **280** espèces d'invertébrés réparties en deux embranchements : les **Mollusques** et les **Arthropodes**, ces derniers sont les représentés dont **273** espèces appartiennent à la classe des Insectes. Elle renferme **15** ordres, les **Coléoptères** est l'ordre le plus représenté avec **103** espèces réparties dans **21** famille. Les **Hyménoptères** comptent **37** espèces. Les **Diptères** sont représentés par 24 espèces dont la majorité reste indéterminée. Les **Orthoptères** avec **23** espèces , les **Hémiptères** et les **Lépidoptères** avec **22** espèces chacun, les Homoptères avec **15** espèces, les **Névroptères** et les **Podurata** avec **6** espèces chacun, les **Odonatoptères** comptent **5** espèces et enfin, les autres ordres sont faiblement représentés.

Diversity and biogeographic considerations of Cuban earthworms (Annelida: Oligochaeta)

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The lack of fossil history in terrestrial oligochaetes, the incomplete exploration of a region and the scarce information on this fauna of many countries obscure the systematics and the biogeography of the group. This is the case of Cuba, where only four native species were mentioned until approximately half of the XXth century. In this work the actual knowledge on the taxonomy and biogeography of the Cuban earthworms, as well as the limitations, challenges, and perspectives on the research of these organisms, will be analyzed. Information on the records included in the lists were obtained from collections realized in the archipelago by the senior author and are deposited in the Edaphic Fauna Laboratory of the Faculty of Biology of the University of Havana. Records obtained from the literature are noted as such in the reference. Native species are considered as those who originate in the area north of the Neotropical region and includes Mexico (to the south of the Anahuac line), Central America and Caribbean Islands. Species that do not originate from this area will be referred to as exotics. Up to now, only 25 % of potential fauna from Cuban archipelago has been identified; this percentage represents 51 species and 24 genera, belonging to eight families. Octochaetidae is the most diversified family (20 species) (39.2 % of total fauna). Ten genera (41.6 %) and 31 species (60.7 %) are natives and endemism reaches 61.3 %. The presence of the genera *Eutrigaster*, *Zapotecia*, *Nematogenia*, and *Onychochaeta* in Cuba and Hispaniola demonstrate affinities between both islands. With Mexico, Cuba shares *Protozapotecia*, *Zapotecia*, *Diplostrema*, and *Phoenicodrilus*. Furthermore, the genus *Cubadrilus*, although present in Cuba but not in the continent, is very close to the Mexican *Zapatadrilus*. In addition, the native Cuban earthworm fauna is related with that of Central America and Jamaica (*Eutrigaster*), as well as that from Puerto Rico and the Virgin Islands (*Trigaster*, s.l.), while the scant influence of the South American fauna on the Antillean, specifically the Cuban one, is corroborated.

The possible way of arrival of megadriles to paleoarchipelago are discussed. Studies on the presence and distribution of earthworms from Cuba are still scanty, especially those dealing with native species. A greater number of samples should be carried out in the mountainous zones of the country, where higher diversity and endemic values of the invertebrate fauna are found because, besides being the geologically oldest, the most conserved and less anthropogenic influenced woodland forests still exist.

Monitoring of soil organisms: A set of standardised field methods proposed by ISO

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Until quite recently, the use of soil organisms (in particular, earthworms, collembolans and enchytraeids) in applied soil ecology was restricted to ecotoxicological laboratory tests. However, following a general trend in soil protection in various European countries, methods being suitable for the assessment of the habitat function of soil (i.e. the ability of soil to act as an environment for organisms) were increasingly looked for. In particular, this demand became obvious when concepts for the biological classification and assessment of soils were formulated in Germany and The Netherlands. Since the biological assessment of a soil could lead to the decision, that actions (theoretically even a remediation of that site) have to be taken, any method to be used has to be standardised and (approved by legislation) legally valid.

In order to avoid re-inventing the wheel, such biological methods (for short summarised as monitoring methods), were taken over from soil ecology. Partly for decades, soil organisms were sampled and extracted for very different scientific purposes. So, it was no problem to identify scientifically robust methods suitable for standardised monitoring. Recognizing the need of harmonization a working group of ISO Technical Committee 190 “Soil Quality” agreed to add three methods to its working program which are currently close to finalisation:

- ISO/CD 23611-1: Soil quality – Sampling of soil invertebrates – Part 1: Hand-sorting and formalin extraction of earthworms
- ISO/CD 23611-2: Part 2: Extraction of microarthropods (Collembola and Acarina)
- ISO/WD 23611-3: Part 3: Extraction of enchytraeids.

However, one method (extraction of nematods) is still missing in order to cover the most important groups of soil organisms used in soil quality assessment. In addition, a guidance paper explaining the most important issues in designing field studies (including statistical advice) is planned.

All ISO draft documents cover the technical details of the most appropriate method but also contain method modifications necessary in special cases (i.e. when working in the tropics). Periodically, these methods are reviewed whether they are still appropriate (i.e. whether new developments have to be implemented). All interested scientists in participating ISO member states are invited to contribute to the improvement of these methods (in particular, the formulation of the guidance paper on the design of monitoring and sampling in the field).

Oligochaeta (earthworms and enchytraeids) and micro-organisms from various secondary forests (Mata Atlântica): Sampling methods and first results of the SOLOBIOMA project

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The diversity of two families of oligochaete worms (Glossoscolecidae and Enchytraeidae) as well as the micro-organisms is sampled in young, medium and advanced secondary forests and pastures under different soil conditions in the Brazilian Mata Atlântica. Two approaches are used: 1.) At six sites, the diversity, assemblage structure and biomass of these organisms is studied with regard to their function in the "ecosystem service" decomposition and the nutrient cycling processes in these forests. 2.) A comparison of the oligochaete fauna and the microbial community of 27 sites in primary and secondary forests (which differ in terms of age, geology, soil conditions and vegetation type) will indicate the factors which determine the presence or absence of species, as well the factors which may be relevant for species richness and community structure. The preconditions for the application of a "regionally differentiated BBSK" approach (Soil Biological Site Classification) will be studied in order to assess its future feasibility for the evaluation of soil quality (i.e. the habitat function of the soil).

One study area is situated in the coastal plain of the Serra do Mar near the town of Antonina (25°25' S, 48°40' W) in the "Área de Proteção Ambiental Guaraqueçaba ("Reserva Natural do Rio Cachoeira"), where Cambisol soils and Gleysols are widely distributed. The natural vegetation is denominated "Floresta Ombrófila Densa Submontana". The other area is located in the "Área de Proteção Floresta do Palmito" near Paranaguá (25°35' S, 48°32'W). There "Floresta Ombrófila Densa das Terras Baixas" grow on sandy Podzol soils on sediments of fluvio-marine origin. The sampling methods for oligochaetes as well as the measurement methods for microbial parameters have already successfully been used in central Amazonia (Höfer et al. 2001).

In this contribution preliminary results from the second approach, covering just nine sites are presented. The species diversity of earthworms is low and does not differ between the various forest and soil types, but abundance and biomass are highly variable. The peregrine glossoscolecid worm *Pontoscolex corethrurus*, indicating anthropogenic stress, is dominant all sites. The enchytraeid communities show a different picture: High taxonomic diversity (mainly species of the genera *Hemienchytraeus* and *Guaranidrilus*, most of them new to science), but at nearly all sites low abundance and biomass. Microbial respiration is rather similar at all sites. However, the influence of environmental factors like soil moisture and land use is clearly visible. Further sampling will show whether factors determining the distribution of soil oligochaetes and micro-organisms can be identified.

Soil properties inside earthworm patches and gaps in a tropical grassland (la Mancha, Veracruz, Mexico)

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Earthworms often form spatially structured populations characterized by alternate clusters of either low or high abundance as well as areas corresponding to random fluctuations around the population mean density. This study compared soil physical and chemical properties between earthworm patches and gaps in order to identify those variables that might explain the observed spatial distribution or, conversely be explained by the population pattern. The survey was undertaken in a tropical grassland (la Mancha, Veracruz, Mexico). Earthworm community was assessed at 100 sampling points regularly located each 5 m on a 20 × 95 m square grid. Soil samples were taken at the same locations to estimate a set of 28 soil descriptors. Those included physical attributes of soil (bulk density), chemical attributes (e.g. pH, K_a Na concentration), texture, vegetation cover biomass and the total carbon content in 3 particle size classes (<50, 200-50 and >200 µm). The spatial pattern was assessed using the SADIE analysis [1]. The aggregation index I_a was 2.623 (p<0.001; Monte Carlo test with 1560 randomisations). Further analyses showed the presence of significant patches (p<0.001) and gaps (p<0.001) respectively corresponding to 37 and 28 % of the plot surface. The distribution exhibited 3 gaps (3 to 21 % of the plot area) and 7 patches (1 to 21 % of the plot area). Because soil descriptors were non-normally distributed with highly heterogeneous sample variances and some degree of autocorrelation, we compared the mean values of explanatory/dependent variables between earthworm patches and gaps using randomisation tests (10,000 randomisations/test). Only a few variables significantly differed between patches and gaps. The grass dry mass was higher in patches (p=0.0057) whereas the mass of other vegetation type was lower (p=0.0091). Clay and silt content were respectively lower (p=0.0012) and larger (p=0.0061) in patches as compared to gaps. There was no variation in the total amount of SOM although the proportion of the total carbon content associated to the fine particles (silt and clay: <50 µm) was higher in the earthworm patches (p=0.0124). The amount of carbon associated to larger particles (>200 and 200-50 µm) was lower in the patches although the difference was not significant (p=0.23 and p=0.06). Patches of earthworm corresponded to an increased proportion of carbon associated with light fractions (<50 µm) that may be resulting from soil digestion by endogeic species. This finding supports the hypothesis that most earthworm species are able to assimilate organic matter from all fractions although fresh residues (large particle size) constitute a more valuable trophic resource. However, the absence of a significant decrease of C associated with the coarse fraction still remains unexplained. The results of this survey also suggested that the vegetation cover and the texture pattern might have an effect upon earthworm spatial distribution.

Reference

- [1] Perry et al. 1999. Ecology Letters 2 106-113.

Re-Colonization mechanisms of soil Collembola after inundation

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Soil microarthropods inhabiting floodplain soils are known to be heavily influenced by inundation. They can, however, quickly regenerate natural floodplain communities within weeks. Different mechanisms for repopulating soils after floodwater withdrawal are known: i.e., withstanding flooding within a “physiological gill”, hatching from flood-resistant eggs, migration from non-flooded areas. However, which mechanism which individual floodplain species possesses is only sporadically known in Europe. Within ongoing investigations of soil-microarthropod community dynamics in floodplain habitats of the Upper Rhine Valley in Germany, field and experimental studies of regeneration mechanisms were undertaken.

In a first study, surface active microarthropods were collected in “barriered” mini-pitfall traps to detect directed migration. In each of two sites, four sets of ten mini-traps each (five on either side of a barrier) were repeatedly set (from July to October 2002) and collected at weekly intervals for up to two weeks after flooding. Recurrent flooding prohibited longer exposition times. The differences of each species caught in front of/behind the barriers were quantified and the results compared with the communities registered during soil sampling in the same sites. In a second study, 50 soil samples were taken from each of the two sites. Of these, ten from each site were extracted immediately and the remainder were experimentally flooded for three days as well as two, four and six weeks (10 samples/site each). After removal from the “floodwaters”, the samples were allowed to “sit” for 7 days and were then extracted. The differences before/after flooding as well as between flooding times were quantified for each species.

Of the species registered during soil sampling, only few were caught in the mini-pitfall traps in appreciable quantities. Even fewer species were caught that were *not* registered during soil sampling. Only some of the trapped species showed directed migration. Of these, a few were apparently migrating from higher elevated areas, while others were obviously migrating *back* towards saturated soils. The experimental flooding apparently killed the majority of the community. Some species, however, survived and were partially present after six weeks of flooding. Of these, a few were even registered as adults after over one month of flooding, indicating inundation tolerance. Others were mostly found as juveniles, indicating hatching from eggs.

The species registered as migrating or present after experimental flooding represent the majority of the initial communities known to occur soon after inundation incidences. The different species showed, however, different methods of re-colonization. Thus, community reestablishment after flooding proceeds through various mechanisms, depending on the different community components. Only some of these species, however, are specific to wetland habitats, which would indicate specific evolutionary adaptations. Others are ubiquitous species, showing that their general life histories can only be regarded as “pre-adaptations” to floodplain conditions.

Nomina Oribatologica Brasiliensis - 1st Approximation

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The oribatids are probably, the most abundant of all mites. Approximately 6000 species have been described (Marshall et al., 1987) and the current rhythm of new descriptions allows us to believe that we are still far from the actual number (from 30000 to 50000) of species (Marshall et al., 1987; Travé et al., 1996). They occur in salt and freshwater, caves, rodent burrows, above and belowground bird nests, in trees and human habitations, but they are most common in soils, where they reach populational densities of more than a million of individuals m⁻² (Marshall et al., 1987). As saprophytes, they have an importance in the soil, being classified according to feeding habits: microphytophages, macrophytophages and omnivores. The microphytophages feed on fungi, bacteria and algae; and the macrophytophages are primary decomposers of the organic substrates (Ehrensberger, 1993).

Because of their ecological importance, despite being difficult to study because of their small size and structural complexity, they are presently object of inquiry all over the world, especially in scientifically advanced countries (Pérez-Iñigo, 1997). However, the lack of specialized taxonomists, as well as the large surface area and environmental diversity in Brazil has greatly limited the study of this group in the country. In the publications Oribatid mites of the Neotropical Region I and II by Balogh and Balogh (1988; 1990), the lack of studies on Brazilian oribatids is clear. The present work is thus the first attempt to list all the families, genera and species of oribatids cited for Brazil.

This list is based on the Balogh and Balogh (1988; 1990), Badejo et al. (2002), Balogh and Mahunka (1992), Balogh (1995, 1997), Fenilli and Flechtmann (1990), Flechtmann (1991), Franklin and Woas (1992a, b), Franklin et al. (1997), Franklin et al. (1998), Niedbala (1981, 1994), Oliveira et al. (2001), Paschoal (1987a, b), Pérez-Iñigo and Baggio (1988, 1989, 1991, 1993, 1994, 1997) Pérez-Iñigo and Pérez-Iñigo Jr (1993), Pinto-da-Rocha (1995), Ribeiro and Schubart (1989) and Woas (1992). The system of classification adopted in this work is that of Balogh & Balogh (1988, 1990).

In this first approximation, 64 families, 158 genera and 324 species of oribatids are listed for Brazil. The families Phthiracaridae (10 genera and 27 species), Opiidae (24 genera and 40 species) and Galumnidae (7 genera and 34 species) contain the largest number of genera and species, while the genera *Xenillus* (18 spp.), *Rostrozetes* (13 spp.), *Galumna* (16 spp.) and *Pergalumna* (13 spp.) contain the largest number of species of oribatids known in Brazil.

State of the art of the taxonomic and ecological knowledge of earthworms in the state of Paraná, Brazil

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The State of Paraná is located in southern Brazil and has an area of almost 200,000 km². Of these 28% are used for agricultural purposes, 34% are in pastures and 14% is forested. Paraná is predominantly agricultural, and grain production reached 55 million tons in 1999. There are five main native vegetation types: *Araucaria angustifolia* forest, cerrado, restingas, native grassland and Atlantic forest. The last one is considered a plant and animal biodiversity hot-spot. This present paper presents the current state of the art of the taxonomic and ecological knowledge of earthworms in the State of Paraná.

Despite the agricultural importance of the State and its biodiversity, few taxonomic and ecological studies had been performed with earthworms. Up to 2001, only three species of earthworms were known from the state: *Amyntas corticis* and *A. gracilis* (VOSS, 1986) and *Rhinodrillus duseni* (MICHAELSEN, 1918). In an ongoing project on earthworm ecology and biodiversity in Paraná, so far 19 of the 399 counties of Paraná have been sampled, adding another 14 species to the list: the exotics *Dichogaster affinis*, *D. bolau*, unknown *Dichogaster* sp., *Eisenia fetida*, *Eudrilus eugeniae* and *Pontoscolex corethrurus* and the native species *Glossoscolex* sp.1, unidentified *Glossoscolecidae* sp. 1, 2 and 3, unidentified sp. 1, 2 and 3 and unidentified *Almidae* sp. 1. Besides these at least 8 other species probably occur in Paraná: *Eukerria eiseniana*, *E. saltensis*, *Diacheta* spp., *Opisthodrilus borelli*, *Glossoscolex corrientes*, *Rhinodrillus brasiliensis*, *Fimoscolex sacii*, and *Amyntas diffringens*. In total there are 17 known (exotic/widespread and native) and 25 probable species for the State of Paraná, of which >40% are exotic. With further sampling efforts, many more species will probably be found.

In the ecological studies, earthworms were rarely identified to the species level, but most used the exotic *Amyntas* spp. Quantitative samples have been performed in various environments: annual cropping (soybean, maize, wheat, beans, oats, millet) in various tillage management, pastures and forests (*Eucalyptus*, *Pinus*, primary forests, secondary forests). These show large populations in no-tillage and pastures, and greater diversity in native forests. Studies have also addressed the effect of exotic earthworm species (mainly *Amyntas* spp.) on plant parasitic nematode damage, on reclamation of degraded areas, on soil physical characteristics, on the growth of soybean, *Bracatinga*, black beans, oats, wheat and on *Rhizobium* nodulation, although much more work is warranted, particularly using species native to the state.

Sampling for abundance and taxonomic diversity assessment of soil macroinvertebrates at various landscape levels

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Large soil invertebrates constitute up to 60% of biomass in taiga ecosystems of European Russia, playing an important role in their functioning. Sampling for abundance and taxonomic diversity assessment of soil animals is usually made by standard methods, by collecting squared or rectangle samples. They vary in a shape from 0.0625 to 1 m² and are located either by a grid or randomly. These methods take into account spatial heterogeneity of soil characteristics.

The study was carried out in August, 2004 in the surroundings of White Sea Biological Station (66°34' N, 33°08' E) in the Republic of Karelia, Russia. The site is located in the northern taiga. The sampling was done in a pine forest on peaty poorly developed soils. By applying a 9-cm diameter corer, the samples were collected up to a depth of 12-15 cm. Two types of scaling were applied. At a plot of 45x45 m size, 100 samples were taken by locating 5 m apart from one another. Besides, in the middle of this area, a plot of 0.5x0.5 m size was chosen. Twenty-five samples were collected here close to each other. The first type of sampling represented a landscape level, while the second one – a local level. General abundance of soil macrofauna was almost two times higher when the second type of sampling was applied (176.7 individuals m⁻², and 301.4, respectively). The number of taxonomic groups was higher at the landscape level of sampling. At the same time, the composition of macrofauna did not differ: spiders, lithobiids and beetle larvae dominated the area. The study was supported by RFBR 03-05-64127 grant.

Treatment conditions of soil samples for estimation of the biomass and fauna of soil protozoa (ciliata and testate amoeba)

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The purpose of this study is to examine soil dispersion conditions for evaluating the biomass and fauna of ciliates and testate amoebae. Based on the review of Foissnor (1999), ciliates and testate amoebae were considered the most effective taxonomical groups for this purpose as biological indicator. The improved techniques gave information of both biomass and fauna of ciliates and testate amoebae in upland soil with slurry application. Possibility of slurry application to diverse soil ecosystem will be discussed.

Dispersion conditions of the pre-treatment of ciliate

Shimano et al. (2001) and Takahashi et al. (2002) suggested that soil ciliates' biomass could be estimated by using the modified MPN method. They, however, did not determine the most efficient method to get most abundance of ciliates and to separate active forms and cysts from soil particles. The soil underwent dispersion treatment using either a vibrating mixer or an ultra sonic cleaner. The survival ratio of the free-swimming ciliate, *Paramecium caudatum*, was more than 90% following any of these treatments. In contrast, when the ultrasonic cleaner was used to treat the soil samples, the number of ciliates detected was less than half those detected using the vibrating mixer.

Dispersion conditions of the pre-treatment of testate amoeba

For the direct count method (Shimano et al. 2002) requires an efficient separation method to get most abundance of testate amoebae from soil particles. The soil particles underwent dispersion treatment using either a magnetic stirrer, recipro-shaker or an ultrasonic cleaner. Thirty minutes of sonication produced the best condition, while the second best condition was 90 minutes of magnetic stirring. We attempted a simple cultural method (Shimano et al. *in press*). Our method amplified genus *Trinema* and *Euglypha*.

Application of slurry to upland soil field

The present investigation was designed to enumerate bacterial populations by using the modified washing-sonic oscillation technique (Hattori 1973), to separate bacterial populations in soil microaggregates, to determine protozoan (ciliates, testate amoebae, nude amoebae, and flagellates) abundance through the use of several techniques involving slurry application.

Water-stable soil aggregates (Large size; 1-2mm) in upland soil relative to slurry application. The counts of viable bacterial also increased in relation to slurry application levels. The above results suggest that microbes might find more living space by higher application of slurry to soils.

The number of nude amoeba, and flagellate as determined using MPN-method did not correlate with slurry application levels. However, the number of testate amoeba as determined using the direct count-method and culture-method and the number of ciliata as determined using modified MPN method was relatively increased with the slurry application levels. We report their fauna compare in the each plot. Moreover, we identify the common and specific species of ciliata and testate amoeba.

The new oribatid mites complexes from the Holocene peat deposits in the northern Russian Plain

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Oribatid mites are extremely abundant in all soils. Their chitin shells have the drop-like, smooth shape and sub-microscopic size, so that they are almost fully preserve in the fossil state. Besides, both alive and dead oribatids can't move far from their habitat. All these features allow to use moss mites as the bio-indicators of the local palaeo-environment.

The fossil assemblages from the former peat mire on the floodplain of the Vychegda River (61°16' N, 44°46' E) were studied. Mites from four samples of the ¹⁴C (non-calibrated) age of 860±60, 3250±65, 4505±55 and 6155±60 years were extracted by the Paraffin Flotation method. Totally more than 400 shells were found. From the sample aged 6155 years B.P., 23 species were identified. Two of them occur at present only in Siberia, two more are found only in the area west of the study site, three species are spread to the south and west of the site. All the other taxa of this fossil fauna occur at present within a broader region including the study site. A new genus *Alexebates* was described from this assemblage. There is no complete recent analogue to this oribatid fauna. From the sample aged 3250 years B.P. 27 species were identified, most of them being of the western distribution type. The closest recent analogue of this fossil fauna is located south-west of the site, thus indicating the climatic conditions more oceanic than at present. Only three species are common for both of these samples. From the 4505-years-old sample 160 oribatid shells were extracted, and a new genus *Palaeonothrus* was described. The 860-years-old sample yielded only 10 shells of the species currently inhabiting the site, except for a single new species.

Under changing landscape and climatic conditions in the Pleistocene and Holocene, peat mires similar to the one we studied represented refuges for the ancient oribatid faunas inherited from older ecosystems, which allowed some taxa to survive until the late Holocene.

Structure of the communities of Collembola in a Mediterranean ecosystem of Spain

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The changes in diversity of Collembola have been studied in the National Park of Cabañeros, Castilla la Mancha, Spain. Six land-use units were chosen following the pattern of Bioasses project, where each one represents a land-use type in a land-use gradient from natural wood till agricultural use. At each unit a grid of 16 sampling points, separated 200 m from each other, were set in a 1Kmx1Km area. The samples were collected in the Spring of 2002.

Biodiversity patterns and relationships with landscapes metrics were analysed. Biodiversity descriptors estimated were: Total species richness, Shannon, Evenness, Margalef, Simpson, Jack Knife and Whittaker \hat{h} -diversity for each habitat. Only 85, 2% of the samples presented Coellobola, making a total of 11842 individuals classified into 79 species, 13 of which are endemic of Iberian Peninsula (10 from Spain and 3 from Portugal). The number of exclusive species was higher in the natural woods and shrubs units (17 and 9 respectively), being completely absent in the agricultural places (LUU6).

The natural (LUU1) and shrubs (LUU3) units have the highest values of richness and diversity, and the agricultural places have the lowest. There is a decrease of these biodiversity descriptors along the gradient of use of the places, from wild unmanaged areas till man-managed ones.

These results indicate that the natural places can act as a reserve pool of species, and shows how the extensive use of the land can disturber and cause the loss of some species of this part of Spain.

The comparison of the nutritional biology of the saprophagous mite communities (Acari: Oribatida) inhabiting two closely neighbouring moss habitats

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Two closely neighbouring moss habitats (covers of *Hypnum* sp. and *Polytrichum* sp. respectively) on the forest soil were studied during two seasons as regards the mite communities structure and especially as regards the nutritional biology of dominant and subdominant dwelling mites as well as rarely occurring species. The latter was estimated by the system of parameters based on the histology, microorganismal plating and enzyme activity tests. The following parameters were analyzed:

- shape and contents of the food bolus,
- presence of the food bolus in each part of the alimentary tract
- microanatomy of the walls of alimentary tract including the enzyme granules, vacuoles and apocrine enzyme secretion
- internal associated extraintestinal bacteria
- excretion of the guanine
- hemocyte forming
- species of bacteria plated from mite homogenate
- chitinase or cellulase production

The cover of moss *Hypnum* sp. differs from the *Polytrichum* sp. as by the dominant species, as by the community structure as by nutritional parameters of the mites. In the *Polytrichum* sp. *Hermannia gibba* including juveniles was dominant, whereas in *Hypnum* sp. *Achipteria coleoptrata* with juveniles was dominant. Both species were panphytophagous. The nutritionally specialized species were rather rare in such communities. These results were discussed with the previous studies of the similar biotopes. These studies were supported by the grants GAÈR 526/02/0681 and Ministry of Education J-3100346.

Small scale spatial patterns of litter-soil conditions and enchytraeid communities in pine-oak forest

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Effects of individual trees of different species on litter-soil conditions and enchytraeid density and species composition were studied in a mixed pine-oak stand on podzolic soil in Niepołomice Forest, Southern Poland. From a 60-year old isolated oak tree surrounded with 46-53 old pines 15 m long transects were set running in N-W, N-E, S-W and S-E directions.

To determine the effect of oak tree upon litter composition dead oak leaves were counted in 200-cm² circular samples in 0.5 m distance on each transect. Every 1 m along the transects, soil cores 10 cm deep were taken to determine the number and diversity of enchytraeids and to measure dry mass of oak and pine roots.

The amounts of oak leaves and roots decreased exponentially with the distance from the tree, disappearing almost completely and being replaced with pine needles and roots at 5 and 3 m, respectively. The number and diversity of enchytraeids did not show any directional change along the transects. Four genera of enchytraeids: *Cognettia*, *Enchytreus* (mainly juvenile forms), *Achaeta* and *Fridericia* were identified in the samples, with *Cognettia* and *Enchytreus* being most numerous.

Patch dynamics and population structure of nematodes and tardigrades on Antarctic nunataks

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In habitable places on Antarctic nunataks (mountain peaks, penetrating the ice sheet) loosely formed assemblages of microscopic animals occur. They form simple food webs, the composition of which may differ among habitable patches of similar kind. Thus in some patches there are no multi-cellular animals while in others several species can form short food webs including primary producers e.g. mosses, algae or lichen, heterotrophic microorganisms such as bacteria and fungi, consumers such as protozoa, rotifers, tardigrades and nematodes, and finally predators among tardigrades and mites. In moss cushions algal or bacterial consumers are found among nematodes, especially species belonging to *Plectus*. In moss there is also a rather frequent occurrence of particle feeding rotifers and plant- or microbial feeding or predatory tardigrades. Among tardigrades species belonging to *Macrobiotus* have been observed feeding on rotifers and nematodes (including *Plectus*). Population structure of tardigrades and nematodes in samples from nunataks in East Antarctica was investigated. The differences in population structure differed among habitable patches of the same kind. This indicates that there is little synchronizing of populations among patches. The effect of predatory tardigrades on abundance and population structure of bacterial feeding nematodes of the genus *Plectus* was also investigated. The occurrence of empty patches and patches in different developmental stages indicate a stochastic population situation.

Comparative studies of soil animal communities (macrofauna) in automorphic and hydromorphic forest soils of Central Russia

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Functional structure of local soil animal communities was studied to assess the spatial diversity of the distribution of soil invertebrates determined by a mesorelief. Field studies were carried out in the southern part of the boreal forest zone in Central Russia (Central Forest State Biospheric Reserve, Tver region). Experimental plots were selected in three forest subecosystems of *Piceeta* forests on the automorphic and hydromorphic positions of the soil catena. The automorphic position was represented by soddy-podzolic soil on a slope position. Hydromorphic soils were developed on plain elevations (high paludification) where occurs the oligotrophic bog soil, and on the alluvial positions in low moors with the eutrophic bog soil.

The method of sampling of standard soil cores (25 x 25 cm) with the subsequent hand sorting of soil from different horizons was used for quantitative investigations of soil invertebrates. 10 parallels were sampled from each experimental plot. Population density, biomass, taxonomic content of local communities were studied to evaluate indices of their α - and β -diversity.

The population density of soil macrofauna in automorphic soils was less than that in hydromorphic ones - it averaged 349 Ind.m⁻², while in oligotrophic soils it reached 400 Ind.m⁻² and in eutrophic habitats – 654 Ind.m⁻². The abundance of soil invertebrates showed the strong dependence on a soil humidity and nutrient supply. The taxonomic composition of animal communities in automorphic and eutrophic habitats was similar and β -diversity between these plots averaged 0.17, whereas it increased to 0.37 between automorphic and oligotrophic plots. β -diversity between both hydromorphic plots was 0,26.

Lumbricids, isopods, molluscs, diplopods, opiliones, larvae of Curculionidae were numerous in both automorphic and eutrophic soils, but these groups were absent in oligotrophic plots. The latter were characterized by the presence of pseudoscorpiones and Blattodea representatives in the litter layer. Epigeic predators were predominant in the structure of animal communities of oligotrophic soils: spiders averaged there 70 % of the total numbers, Staphylinid and Carabid beetles – 5 and 4.8 % respectively. Polydominant communities were characteristic of eutrophic soils, lumbricids being especially numerous there. The larvae of dipterans consist almost 10 % from the total number, what is characteristic of invertebrate communities in taiga soils. In the automorphic soils dipterous predatory larvae were excluded out of the dominant group. Lumbricidae maintained there the predominant position. The group of predators was represented by staphylinids, spiders and lithobiids.

Soil animal communities in the habitats on different mesorelief positions were found to vary by the population structure and diversity. The Shannon diversity index averaged in the automorphic plots 2.39, the intra-habitat variations being 32,3 %, and that in the poor oligotrophic soils was 1.01 with the intra-habitat variations 18 %. The Menhinick index of species richness was maximal in the automorphic communities (4.06), in swamping soils it lowered to 3.3 in eutrophic and to 1.9 – in oligotrophic communities respectively. The structural variations of local communities reflect their functional differences in the soil biodynamic and impact to the ecosystem balance.

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Abundance, biomass and diversity of earthworm communities in Central Ivory Coast

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The community structure and diversity of earthworms of a savannah protected from fire since 1967 were monitored for a period of 19 months on a 95 x 50 m experimental plot. Earthworms were sampled at monthly intervals from June 1994 to December 1995, using direct hand-sorting techniques. Each month, 10 monoliths of 1 m² x 40 cm dimensions were selected from a stratified bloc design.

The dynamics of total earthworm populations were seasonally determined. This was confirmed by a significant correlation between the log of population density and soil water content ($r = 0.98$, $p=0.00000$) on one hand and the biomass and soil water content ($r = 0.87$, $p = 0.000001$) on the other. Ten earthworm species were collected. The dominant earthworm species belong to the family Eudrilidae (*Chuniodrilus zielae*: 73.3 ± 8.9 ind m⁻²; *Hyperiodrilus africanus*: 30.2 ± 4.3 ind m⁻², *Sthulmannia porifera*: 11.5 ± 1.2 ind m⁻²) and account together for 73.2% of the community. The Megascolecidae *Millsonia anomala* (10.6 ± 1.3 g m⁻²) and the Eudrilidae *H. africanus* (7.1 ± 1.1 g m⁻²) contributed at 65.6% to total biomass.

Species accumulation curves were similar for both observed species and the total expected species number. This finding pointed to the efficiency of large quadrat of 1 m² x 40 cm for sampling. Sorensen's index revealed differences in the composition of the earthworm community at different seasons. The implications of seasonal change related to the variation of earthworm diversity are discussed.

Key words: Community structure, biodiversity, tropical earthworm, seasonal variation, similarity index

Modelling the demography of a tropical earthworm under periodic environment

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It is well known that tropical earthworm demography is under the control of soil water content as two contrasting periods alternate during population dynamics: growth in wet season and decrease during the dry season. Populations are then characterized by seasonal periodicity of change in vital rates with two main features: soil consumption, growth and reproduction during wet season and quiescence in dry season. This pattern reproduces periodically each year. An age-classified matrix model was built to assess the impact of periodic environment on the viability of a population of *Hyperiodrilus africanus* using a binary index q (quiescence indicator: $q=1$ for quiescent individuals and 0 for active ones) to represent periodic changes in the environment. Field and laboratory data were used to parameterize the model.

The results give the growth rate $\lambda = 1.027$, showing that populations are closed to stability. The growth rate λ was more sensitive to change in the survival of immature individuals. The outcomes are in agreement with field and laboratory observations for *H. africanus* populations. Adding environmental noise to the model showed that extinction can occur in the long run. Over 20 years, the extinction time was about 1 year, the probability of extinction was 10% and the population growth rate was close to 1.0.

The results of the viability analysis of *H. africanus* populations seem to indicate that in short-lived tropical earthworms, abiotic regulation may take precedence over density-dependent regulation.

Key words: Matrix models, tropical earthworms, *Hyperiodrilus africanus*, viability analysis

New Records of the family Opilioacaridae (Acari: Parasitiformes) in Mexico, Cuba and Dominican Republic

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The Opilioacaridae family is widely distributed throughout the tropical and warm temperate zones of the world. Only 23 species in 8 different genera have been described. Most of this diversity has been reported from the old world. Three of the last described species, *O. siankaanensis*, *O. nohbecanus* and *O. bajacalifornicus*, belong to México, Vazquez and Klompen (2002). A survey of soil fauna in Cuba, Dominican Republic and Mexico resulted in the finding of new records to these countries.

A number of additional records have helped to flesh out the distribution pattern of Opilioacaridae in the NewWorld. Hoffman and Vázquez (1986) reported Opilioacaridae from the State of Baja California Sur in México, Palacios Vargas and Vazquez (1988) reported them from Nicaragua while Kaiser and Alberti (1991) and Klompen (2000) recollected *O. texanus* from central Texas. Recently Vázquez and Klompen (2002) described four new species from México and Nicaragua.

Survey on soil fauna in México, Cuba and The Dominican Republic allowed us to get more exemplars of the Family Opilioacaridae and to discover new geographical sites of distribution and habitat selections for these mites. Most specimens were extracted from litter using Berlese Funnels. Additional specimens were obtained by manual collecting from under rocks and loose bork of fallen logs. All material from Cuba and the Dominican Republic was collected by hand.

Most material was studied as slide mounted specimens, although some were examined using temporary preparations in cavity slides.

Material examined:

Mexico; El Morro, Veracruz in Coastal dunes 150 , 6 juveniles .México, Calakmul biosphere reserve, Campeche. Mature tropical Forest, litter and roots of *Swietenia macrophylla* 10 , 6 , 4 juveniles coll. M.Vazquez ; Cuba 4 , 1 , 1 juvenile in litter of a fine –oak forest surrounding La Habana and 2 , 1 , 1 juvenile from a fine oak forest near Santiago, Cuba, coll. Diana Prieto ; and 2 , 1 juvenile from Xerophytic shrubs in the Dominican Republic. Coll.Luis de Armas.

Habitat preference for *Opilioacaridae* is often described as “arid” or “semi-arid” areas. Such a description does fit the Collection sites for the Old World species. Even so, this generalization is clearly overly broad.

Most of the species found in Mexico, Cuba, Nicaragua, Belize and Venezuela were collected from tropical forest litter, under stones, under bark, sand from dunes, and even though between roots in the soil, as well as, in a pine-oak forest litter in Cuba and Belize.

These new records show that there is a considerable variability in habitat types occupied by the species of the family Opilioacaridae, specially in the New World.

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Keywords: Opilioacaridae, México, Cuba, Dominican Republic.

Army ants – an important part of the subterranean predator guild in forests and agroforestry systems in Central Amazonia (Formicidae, Ecitoninae)

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Diversity and biology of the hypogaecic ant fauna is still poorly known in the tropics mainly due to methodological difficulties. As part of the research activities of the SHIFT Project ENV 52-2 near Manaus, Brazil, we studied the baiting effect of palm oil for neotropical ants. Here we present results on subterranean army ants (Ecitoninae).

We offered palm oil as bait in eight different habitats at the experimental study site of EMBRAPA-Amazônia Ocidental near Manaus, Amazonas. Among these habitats were two different primary forests, two secondary forests of different age and three agroforestry systems: coconut palms (*Cocos nucifera*) in a matrix of the creeping legume *Pueraria phaselioides*, monocultures of peach palm (*Bactris gasipaes*), and monocultures of rubber trees (*Hevea brasiliensis*). In total, we studied 80 plots with three sampling points, each, consisting of two palm oil baited points and one control point without bait. The first sample of each plot was collected one day after exposing the oil bait, the second one after seven days. Altogether, 240 soil discs 15 cm thick and 21 cm in diameter were taken with a cylindrical soil core sampler and exposed in Berlese funnels to extract the macrofauna.

Ecitonine army ants (2 *Labidus* and 3 *Neivamyrmex* species) occupied 64 of the sampling points baited with palm oil (40%). Only at 4 control points without palm oil army ants could be encountered (5%). The differences in individual numbers were quite impressive: 71757 (99.94%) army ant workers were counted from the 160 palm oil baited soil cores, but only 45 (0.06%) from the 80 unbaited ones. The differences between baits and controls (presence-absence data) were highly significant ($p=0.001$ for the baits after one day exposure, $p<0.001$ for baits after 7 days exposure, and $p<0.0001$ for the combined baits, Fisher's test).

Army ants were attracted in all of the investigated habitats. Significant higher frequencies could be detected only in the plots under coconut trees, under *Pueraria* cover and from the peach palm monocultures. Under coconut and peach palm trees this preference was correlated with a 10 times higher abundance of earthworms (mainly *Pontoscolex corethrurus*) in comparison to the other habitats and, under coconut trees, additionally with 3-fold higher numbers of soil macrofauna (especially ants, diplopods, isopods and termites) in the litter/humus-layer. This rich food source might influence the presence of army ants also in the *Pueraria* matrix, where such high macrofauna values were not found. The peach palm monoculture additionally may be attractive due to its long-time presence of oil-containing fruits, because many of them were not harvested in the experimental cultivation.

Our results demonstrate that the abundance of army ants in neotropical soils must be considerable although they are not obvious to the observer because of their hidden, hypogaecic lifestyle. We also conclude that the large numbers of hypogaecic army ants should be able to significantly influence the population size of many other subterranean species of the soil macrofauna.

Transition from organisational phase to mosaic-cyclic state at the end of primary succession – observations on myriapods

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Myriapod species composition was studied in the oldest stages of a 50-year investigation of primary succession on land reclaimed after lignite open-cast mining. The results were compared with the native communities of woodlands in the surroundings. Since the myriapod species inventory in the reclaimed sites is the result of a very long succession in its organisational phase, the question arises whether any differences to the typical species assemblages in native habitats within the mosaic-cyclic state continue to exist. Using faunistical and ecological qualitative analyses and the evaluation of the quantitative coenotic similarities, a possible transition point from a primary successional development to a mosaic-cyclic state can be defined. For this, centipedes exhibit more differentiable characteristics, especially regarding life-forms, than millipedes do. Appropriate sampling methods are essential for guaranteeing useful information.

Geographic determinants of oribatid mite communities structure and diversity in Europe

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Majority of soil-zoological studies are focused on the very limited areas and do not take into account geographic variation of the habitats. However for appropriate comparison of results of various applied studies on oribatid mites consideration of the strong bias in the taxonomic and functional structure and diversity induced by geographic factors at different resolution scales is required. The effect of geographic position determines these oribatid community characteristics through three overarching forces: mother rocks, relief and climate.

We studied changes in the oribatid community structure, composition and diversity in Europe along two transects, first – with West-East direction in the deciduous forests zone from the sea coast in the Netherlands till Moscow region in Russia (five sites) and the second – with North-South direction from middle Sweden to Italy (six sites). There was straight climatic gradient in the first transect as the sites were situated at different elevation. In each site sampling was performed at least twice. Organic layer and top 5 cm of mineral soil were taken. Sample size was harmonized for all sites.

There is a strong impact of continentality on oribatid diversity and functional structure. There are more species found moving further from the sea in the Netherlands until Poland (50 and 96 species respectively). Then it drops down dramatically in Russia (48 species). Also there is a constant increase of surface-dwelling mites relative abundance moving to the East, which are better protected against harsh climate.

In the North-South direction no clear oribatid diversity trends could be established. Local variability of abundance and species richness was higher than between transect site. There were strong shifts in community faunistic structure, especially in the site in Italy, where several species with Mediterranean and some untypical for Europe distribution types were found. Also relative abundance of specialized fungivorous mites was increasing southwards (from 30 to 85% of the total oribatid abundance). This growth reflected general shifts in the soil foodweb structure moving southwards.

Species turnover rate increases moving Southwards and eastwards relative to the northernmost and westernmost sites respectively. In the first case it is determined by strong shifts in taxonomic structure of oribatid communities especially in Italy compared with the transect sites to the North from Alps. In the second one is ensured by increasing species diversity until Poland and then its strong decrease in Moscow region.

We conclude that type of mother rocks and relief which do not show any zonality patterns are very important for taxonomic structure of oribatid community in European deciduous forests as they form natural barriers, determine soil type and many soil abiotic properties. Climate affects more numerical diversity and functional structure possibly through temperature-moisture regime and partially through natural forest type.

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Earthworm flooding ecology

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Terrestrial earthworms are well adapted to moist conditions. Their activity is higher in wet soil and some species are known to be able to survive for a long period in water. They are, however, not aquatic organisms and many have reported earthworms' avoidance of very wet places, escape behaviour when placed in water, or found dead in pools after rain. These characteristics in earthworm ecology are contradictory. Explanations may be found in optimum ranges or species differences.

The objective of this study was to clarify the relation between earthworms and water excess to get a better insight in earthworm flooding ecology.

From October 2000 until May 2003 earthworm samples were taken in the 'Afferdensche and Deestsche Waarden' (ADW) floodplain. This is an embanked floodplain on the south bank of the river Rhine in the Netherlands. The floodplain has been flooded four times during the sampling period. Several times a year earthworms were sampled, counted and weighed per species.

The average number of earthworms in the ADW was 903 ind./m² (SD 377) and the average biomass was 156 g/m² (SD 57), but both were much lower after each flooding event. Dominant species were: *Aporrectodea caliginosa*, *Allolobophora chlorotica* and *Lumbricus rubellus*. The decrease in number and biomass was highest for *L. rubellus*, while the biomass of *A. chlorotica* did not decrease after flooding.

Three laboratory experiments were performed to further investigate differences in reaction to flooding between the earthworm species.

The experiments were set up to determine if:

- 1) these earthworm species are able to survive flooding and a combination of flooding and heavy metal pollution.
- 2) these earthworms have a clear moisture preference and are able to avoid flooded conditions.
- 3) these earthworms could survive different moisture conditions and what the impact of different soil moisture levels is on the earthworm condition. Condition in this case was defined as the dry weight/ wet weight ratio.

The laboratory experiments showed some differences between the species tested. *A. caliginosa* and *A. chlorotica* were tolerant towards flooding, although they did avoid completely inundated conditions. *L. rubellus* had a strong reaction toward flooding, shown by escaping behaviour and by refusing to burrow. Each species was, however, able to survive inundation for 6 weeks, although their condition decreased.

It is concluded that earthworms are capable of surviving a high excess of water, (hence extended periods of inundations of several weeks) but that other factors caused the decline of population numbers. *L. rubellus* stays uncovered above the soil surface during flooding events, making it vulnerable to predation and more susceptible to solar radiation. *A. caliginosa* and especially *A. chlorotica* hardly show this change in behaviour and are more tolerant to flooding. The differences between the species towards flooding seem to reflect the differences in ecological classes (epigeic, endogeic anecic).

SESSION 3

Soil Animals, Nutrient Cycling and Soil Fertility

ORAL CONTRIBUTIONS

Effects of humic acids extracted from earthworm-processed organic wastes (vermicomposts) on plant growth

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It has been suggested that the significant increases in microbial activity that occur during the breakdown of organic waste by interactions between earthworms and microorganisms could produce significant quantities of plant growth hormones and humic acids which acts as plant regulators and accelerate growth. Experiments were designed to evaluate the effects of humic acids and compare the action of humic acids in combination with a commercial plant growth hormone, indole acetic acid (IAA). In the first set of experiments, humic acids were extracted from cattle, food and paper-waste vermicomposts using an alkali/acid fractionation procedure which produced 1 g dry wt humates from 400 g vermicompost. They were applied to a soilless growth medium, Metro-Mix 360 (MM 360), at rates of 0, 250 or 500 mg humates kg⁻¹ dry wt of container medium, to young marigold, pepper, and strawberry plants, grown in pots in the greenhouse. A range of 0, 20, 100, 150, 200, 250, 500, 1000, 2000, 4000 mg of humates kg⁻¹ of container medium was used for tomatoes. Effects of the humic acids on the plant heights, leaf areas, shoot dry weights, root dry weights of peppers, tomatoes and marigolds and numbers of fruits of strawberries were assessed. Substitution of humates ranging from 250-1000 mg kg⁻¹ MM 360 increased the root growth of marigolds and peppers, and increased the root growth and numbers of fruits of strawberries significantly (P < 0.05). Leaf areas, plant heights and above-ground dry matter weights increased considerably in plants grown in pots treated with humic acids but they were not significantly different from those grown in MM 360 only (P > 0.05). In other experiments, humic acids extracted from food waste vermicomposts were used at a rate of 500 mg kg⁻¹ dry wt of MM 360 applied singly or in combination with IAA at a rate of 10⁻⁵ μM, to young pepper seedlings in 10 cm pots with 10 replications. Humic acid produced commercially was used as another standard comparison treatment. Leaf areas, plant biomass, plant heights, number of flowers, numbers of fruits and weights of fruits were recorded over a thirteen week period. There were no significant differences in leaf areas, plant biomass or plant heights between peppers treated with humic acids, IAA and humic acid + IAA with those of plants grown in MM360 (control). However, the numbers of flowers and number of fruits increased significantly (P < 0.05) in peppers treated with humic acid, IAA and combination of humic acid and IAA. Peppers treated with humic acids extracted from food waste vermicomposts produced significantly more number of fruits and flowers than those treated with commercially-produced humic acids. These experiments confirmed that humic acids extracted from vermicomposts produce hormone-like effects on plant growth.

Effects of earthworm introductions on soil processes, plant production and other soil biota in agricultural systems and reclaimed land

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Earthworms have been both accidentally and deliberately introduced to a wide variety of agricultural habitats. Deliberate introductions have sometimes been part of more extensive restoration programs, following habitat degradation (e.g. mining, peat harvesting) or reclamation of land from the sea (e.g. polders). Introductions have been on both a large scale (many hectares) and much smaller scale (enclosures of a few square metres). Motivation to introduce earthworms has been driven by needs to improve soil properties (e.g. nutrient turnover, soil structure and water flow, pH, functional biodiversity, food sources for vertebrate predators) and to increase plant production. Frequently, exotic earthworms comprise the majority of the earthworm fauna in agricultural land (e.g. accidental introductions in New Zealand and Australia) and these earthworms provide various beneficial ecosystem services. However, the impacts of introduced earthworms have not always been positive and rates of improvement in site characteristics have frequently been slower than desired following deliberate introductions. Careful site selection and preparation is often paramount for success. “Non-target” effects of exotic earthworms need to be considered prior to deliberate introduction, as with other exotic incursions (e.g. release of biocontrol agents).

This paper will provide an overview of several case studies of accidental and deliberate earthworm introductions in disturbed land, taken from different parts of the world with varying climatic regimes, from the point of view of the impact that has occurred on soil properties, plant production and the abundance and diversity of other soil biota (both invertebrates and microbes, but native earthworms especially). We will indicate the exotic earthworm species that have most successfully colonised such habitats and explore the potential of invasive earthworms to influence the abundance of above ground taxa (pests and beneficial species) there. We shall also discuss the contribution that studies of such invasions can make to the field of invasive biology in general.

Earthworm introductions into farms and reclaimed land have provided insight into the capacity of these invertebrates to disperse and the environmental factors that influence their abundance, through studies of patterns in establishment and the development of rearing methods that have been devised to enable large scale inoculations. We will discuss temporal patterns in establishment (successional processes) that have been observed in disturbed habitats.

Temporal changes of decomposer assemblages structure and functioning during beech forest growth

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Temporal dynamic of forests is a key factor for assessing ecosystem performances (e.g. nutrient cycling, carbon storage). However, only a few studies focused on temporal changes of important system compartments such as decomposer assemblages. The questions we addressed in this study were: Does the developmental stage of forests matter for the soil fauna and the microbial communities? If yes, do all biota show a similar response and what is the incidence on the structure of the decomposer assemblage? And finally, how do potential differences in the response patterns relate to ecosystem processes?

Four secondary beech (*Fagus sylvatica*) monocultures forming a chronosequence including 30-, 62-, 111-, and 153-year-old stands were selected in Leinefelde (Germany). The oldest site also included patches of young beech trees (ca. 16-year-old) that were allowed to grow in the understory to ensure natural regeneration. In the following text these sites will be abbreviated to 30 S, 62 S, 111 S, and 153+16 S, respectively. Micro- (Nematoda), Meso- (Collembola, Mesostigmata, Enchytraeidae) and Macrofauna (Lumbricidae, Araneidae, Isopoda, Chilopoda, Coleoptera, and Diplopoda) were sampled at two sampling occasions in 2000 and 2001 using standard methods. Additional samples were collected from comparable layers to assess abiotic and microbial parameters (microbial biomass, C mineralisation (C_{min}) and ergosterol content).

Soil fauna groups and microbial parameters were significantly impacted by stand age. The ergosterol content was significantly higher at the 62 S than at the 111 S. Though none of the microfauna or mesofauna groups showed a significant response to the factor stand age at the level of overall abundance, significant changes occurred at the functional level. The densities of epedaphic and hemiedaphic Collembola increased with forest age. A similar trend was observed for several macrofauna groups (Chilopoda, Coleoptera, and Isopoda). Earthworms, in contrast, were more abundant at the younger than at the subsequent stage. Finally several correlations between the different parameters (soil faunal groups, abiotic and microbial parameters) were found. For example, a significant positive correlation between the abundance of Nematoda and C_{min} suggests a stimulating influence of microfaunal grazing on microbial activity.

Several dynamic changes characterize the decomposer assemblage during beech forest maturation. Differences in the response patterns of different mesofauna groups indicate compensatory effects of two abundance-regulating processes: bottom-up and top-down effects. However, though each stage of the chronosequence hosts a particular (functional) soil food web, influences on processes such as decomposition efficiency and soil nutrient cycling seem to be small.

Long-term consequences of biochemical and biogeochemical changes in the Horseshoe Bend agroecosystem, Athens, GA

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Understanding many soil processes, including the accumulation of organic matter and the formation of soil aggregates, requires research that is conducted over decadal time periods. The dynamics of soil organic matter (SOM) and soil fauna at the Horseshoe Bend (HSB) agroecosystem site in Georgia have been studied in replicated experimental plots since 1978. Analyses indicate that the experimental treatments (no-tillage and conventional-tillage regimes) are continuing to diverge in amounts and distribution of SOM.

Our research has focused on two major areas: 1) long-term measurements of the gradually-increasing base of soil organic matter from C3-pathway plants, in winter cover-crop and summer crop rotations that have been in effect since 1997; 2) following the production, accumulation, fate and ecological effects of the Bt proteins from the summer planting of Bt (and non-Bt) cotton in subplots within our main plots. The relationship between these focal areas follows. The variation in the size of soil aggregates may influence the sequestration of Bt toxins, and their breakdown products, within soils. We have already shown that no-tillage management systems at HSB generate an increasing representation of soil macroaggregates in comparison to the markedly reduced macroaggregates in our conventional tillage plots. We suggest that no-tillage systems will therefore sequester more Bt-related products than will conventional-tillage plots. In midsummer, there were higher numbers of canopy arthropods on the Bt cotton compared to non-transgenic plants at our site. Aphids dominated the samples. Litter macroarthropods were sampled six times a year, using pitfall traps. Higher numbers of litter-dwelling macroarthropods occurred on plots with Bt cotton compared to non-Bt. In addition, over twice as many morphospecies of macroarthropods occurred in NT compared with CT cotton. Litter microarthropod species richness is slightly lower in Bt than non-Bt plots. Other non-target organismal effects seem minimal after three years.

Decomposer animals (earthworms, collembolan) affect above-ground productivity and species dominance in a plant diversity gradient

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Soil decomposers influence soil structure and nutrient mineralisation as well as the activity and composition of the microbial community and therefore likely affect plant performance and plant competition.

A greenhouse experiment was set up to study the effects of decomposers (earthworms and collembolans) on plant productivity and nitrogen uptake in a model grassland community. 43 common species of Central European Arrhenatherion grasslands, consisting of four functional groups (grasses, legumes, small herbs, tall herbs) were transplanted into microcosms in different combinations, with plant species numbers varying from 1 to 8 and plant functional groups (FG) varying from 1 to 4. Earthworms (*Lumbricus terrestris*, *Aporrectodea caliginosa*) and Collembola (*Protaphorura fimata*, *Heteromurus nitidus*, *Folsomia candida*) were added to microcosms to establish four treatments: no animals, earthworms only, collembola only, earthworms and collembola.

After three months above-ground productivity was significantly increased in decomposer treatments but the effect depended on plant species diversity and presence of legumes; animal effects were stronger at low plant diversity and were counteracted by legumes at high plant diversity. Plant FG diversity but not plant species diversity significantly affected total plant biomass. Presence of legumes increased total plant biomass production whereas presence of grasses decreased above-ground productivity.

Decomposers increased plant biomass production by their effects on litter decomposition and nutrient mineralisation subsequently leading to increased plant nutrient acquisition. However, the greater nitrogen availability in treatments with legumes apparently reduced the nutrient effects of decomposers. The results clearly demonstrate that soil decomposer organisms are an important structuring force for plant community composition.

Interactions between three bacterivorous nematode species: effects on population development, bacteria and nitrogen mineralization

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The importance of soil fauna and the diversity of soil trophic groups for ecosystem processes have been determined in many studies. However, there is hardly any knowledge on the nature of the interactions between soil organisms within trophic groups and the importance of these interactions for ecosystem processes. Detailed knowledge on this subject is needed for a mechanistic understanding of the role of biodiversity in ecosystem functioning. We studied the effects of interactions between bacterivorous nematode species on population development of individual nematode species, growth and biomass of bacteria and nitrogen mineralization.

We will present the results of a microcosm experiment with three bacterivorous nematode species (*Bursilla monhystera*, *Acroboloides nanus* and *Plectus parvus*). Treatments comprised all single species and all two-species combinations. We measured nematode population development, bacterial biomass (direct counting), community composition (DGGE) and growth rate (thymidine and leucine incorporation), and mineralized nitrogen.

All nematode species interacted with each other, but the nature and effects of the interactions depended on the specific species combination. *B. monhystera* and *A. nanus* interacted in a highly asymmetric competition pattern. Numbers of *A. nanus* were reduced by competition with *B. monhystera*, whereas the latter was not affected by the first. This interaction affected the bacterial community composition and growth rate, but not the nitrogen mineralization.

B. monhystera and *P. parvus* interacted in a contramensal pattern. Although *P. parvus* was present in very low numbers it stimulated *B. monhystera*. *P. parvus* itself, however, was reduced by *B. monhystera*. This interaction affected the bacterial community composition and increased the bacterial biomass, but the bacterial growth rate was not affected. Furthermore, nitrogen mineralization was increased.

Lastly, *A. nanus* and *P. parvus* interacted in a contramensal pattern similar to *B. monhystera* and *P. parvus*, although the competition effects were less clear than in the former case. However, this interaction did not affect bacterial community composition, biomass or growth rate, and neither did it affect nitrogen mineralization.

The interaction that affected ecosystem properties the most was the interaction between *B. monhystera* and *P. parvus*. These nematode species strongly differ in their life-history strategies, whereas *A. nanus* has a life-history strategy in between *B. monhystera* and *P. parvus*. Possibly, the degree of differences in life-history strategies between species affects their joint effect on ecosystem processes. We conclude that interactions between nematode species occur and may be important for ecosystem processes depending on the species involved. Thus, our results support the idiosyncratic hypothesis that changes in diversity result in changes in function, but the direction and magnitude of the response(s) are unpredictable (Ritz & Griffiths 2001).

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SESSION 3

Soil Animals, Nutrient Cycling and Soil Fertility

POSTER CONTRIBUTIONS

C to N ratio strongly affects population structure of *Eisenia fetida* in vermicomposting

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Growth and reproduction are two major traits in life history of organisms that compete with one another for limited resources. In earthworms it is reported that different mixtures of organic residues enhanced only growth, reproduction or both at the same time and that earthworm's growth is limited by carbon availability. Therefore it seems that earthworms' allocation to growth or reproduction depends on either possible resource limitation or quality. This is important in vermicomposting systems where high growing and reproduction rates are required to accelerate residue breakdown and stabilization.

With this work we tested the hypothesis that C to N ratios of organic manures may affect growth and reproduction of earthworms strongly; besides we studied if the effects of earthworms on microbial biomass and activity were affected.

We used two pig slurries with different C to N ratio: low (11) and high (19). We set up vermireactors for both high and low C to N, with (n=3) and without earthworms (n=3). Initial population of earthworms was 500 mature individuals of *E. fetida*. A complete characterization of the earthworm population (numbers and biomass of cocoons, hatchlings, juveniles, preclitellates and matures) was done in each reactor. Microbial biomass (substrate induced respiration) and activity (basal respiration) were also analysed.

Population of earthworms clearly differed, with significant higher earthworm numbers and biomass in the high C:N treatments. Population structure was also affected, with higher numbers and biomass of preclitellate and juvenile earthworms in the high C:N treatments; no differences were found between mature numbers and biomass although the mean individual weight of mature was lower in the high C:N treatment. Number of hatchlings was significantly larger in the high C:N treatments but no differences were found in cocoon numbers.

We reported a significant increased microbial activity and biomass in both C:N treatments but this was greater in the high C:N treatments.

Effects of compost and vermicompost on the growth of tomato (*Lycopersicon esculentum*) and on the suppression of plant disease caused by *Phytophthora infestans*

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Research on transformation processes of organic wastes into valuable organic substrates, such as compost and vermicompost, has increased significantly during the last years. Both, compost as a product of thermophilic processes and vermicompost as a non-thermophilic biodegradation product resulting from the interaction between earthworms and microorganisms have shown beneficial effects on plant growth and plant health.

Our aim was to investigate and to compare the effects of different amounts of compost and vermicompost on the growth of tomato and on the suppression of plant disease caused by *Phytophthora infestans*. In doing so, tomato seedlings were transplanted into pots which contained a mixture of commercial peat potting substrate and different proportions (0, 10, 20, 50, 75 and 100%) of either compost from cow manure or vermicompost from pig manure. The experiment was conducted under greenhouse conditions and consisted of five replicates per treatment. Inorganic fertiliser was applied twice a week to all plants. In order to assess the influence of compost and vermicompost on the suppression of *Phytophthora infestans* a spore solution was injected into the potting media after plants had been growing for 4 weeks. Plants were harvested after 10 weeks and were assessed for height, number of leaves as well as fresh and dry mass of shoots and roots. Additionally, several chemical and biochemical analyses of the substrate mixtures were carried out before and after the experiment. Plants grown in 10% and 20% of compost were significantly higher and had more leaves than plants with no or a 50% compost substitution. Tomatoes transferred into 100% of vermicompost reached similar heights than plants in 10% and 20% of compost. Plants grown in the commercial peat media without compost or vermicompost addition were significantly smaller than tomatoes in media with low compost or high vermicompost proportion. All plants transferred to 75% and 100% of compost proportion died within the first 3 days. Although *P. infestans* spores developed well in the substrates, no signs of a plant infection could be determined at the end of the experiment.

Our experiment showed that small proportions of compost (e.g., 10 % or 20 %) or greater proportions of vermicompost (e.g., above 50%) in potting substrate could significantly enhance plant growth, however did not affect plants' susceptibility to *P. infestans*. Since all plants were sufficiently supplied with nutrients other factors than the increase of nutrients, like for instance the appearance of plant growth regulators in compost and vermicompost can be suspected to be responsible for the results seen.

Leaf litter decomposition in natural and plantation forest of the Lama forest reserve in Benin

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The Lama forest reserve in southern Benin comprises timber and fuelwood plantations as well as some of the country's last vestiges of semi-deciduous lowland forest. The reserve is intended to protect the fauna and flora and to promote the sustainable use of tree plantations. An important aspect in its management is the preservation of soil quality which in turn is related to key ecosystem processes such as decomposition. In the present study, we examined the decomposition of leaf litter from two indigenous (*Azelia africana* and *Ceiba pentandra*) and two exotic tree species (*Tectona grandis* and *Senna siamea*), using the litterbag technique, and the relationship between decomposition and the relative abundance (frequency of occurrence) of litter-dwelling invertebrates. The study was conducted over a 140-day period, focusing on four different forest types: semi-deciduous forest, young teak, old teak and fuelwood (mainly *S. siamea*) plantations. With the exception of teak, decay rates coefficients (k) were higher than in most tropical forests, ranging from k = 1.3 (*T. grandis* in firewood plantations) to k = 4.7 (*A. africana* in natural forest). Both main factors, litter species and forest type, had a significant effect on decomposition (P < 0.001). The residual litter weight was lowest in *A. africana*, intermediate in *S. siamea* and *C. pentandra* and highest in *T. grandis*. Differences were significant (P < 0.05) for all but one pairwise comparisons (*A. africana* vs. *S. siamea*). With regard to forest type, decomposition was highest in natural forest, followed by young teak, old teak and firewood plantations. Except for teak plantations (young vs. old teak), all comparisons were significant (P < 0.05). We also found a significant litter × forest interaction (P < 0.05), indicating dissimilar changes in decomposition across forest types. The frequency of occurrence of invertebrates differed among leaf litters and forests (P < 0.001), while there was no significant litter × forest interaction. Higher frequencies were observed in indigenous than in exotic litter (P < 0.05). Likewise, litterbags in natural forest attracted more invertebrates than those in forest plantations (P < 0.05). We found a strong linear relationship between invertebrate frequency and litter decomposition (P < 0.001), indicating that the breakdown of litter depended largely on the activity of invertebrates. Our study concludes that management practices should aim to enhance decomposer communities to safeguard the productivity and sustainable use of Lama forest.

Keywords: Natural forest; Plantation forests; Litter decomposition. Litter-dwelling invertebrates; Lama forest reserve.

Earthworm species-specific alteration of mineral nitrogen uptake by rice

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We have investigated the effect of earthworms on rice production in soils added with increasing amounts of mineral N (0, 25, 100, 400 and 1600 μ M). We tested the hypothesis that earthworms affect plant growth via an alteration of N uptake efficiency. Two different earthworm species were used, separately or in combination: *Millsonia anomala*, an endogeic mesohumic species with compacting effects on soil and *Chuniodrilus zielae*, a polyhumic endogeic with decompacting effects. Presence of earthworms increased significantly above ground production by 8 (*C. zielae*) and 14 % (*M. anomala*) respectively. Combination of the two species improved significantly production by 18%. When compared with control for each nitrogen concentration by the GLM procedure, *Millsonia anomala* increased significantly plant growth in the 25 μ M treatment, whereas *Chuniodrilus zielae* increased significantly plant growth in the 1600 μ M treatment. The combination of both species increased significantly production in control, 25 and 1600 μ M treatments. Non-linear regression procedure on plant production showed significant differences among all treatments except for M and D. These results show a significant impact of earthworms on N uptake by plants, and different responses of plants depending on earthworm species.

New insights into the functional significance of soil biodiversity in soil carbon cycling

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The fate and transfer of carbon in soils are dependant upon a complex web of feeding interactions between soil organisms – from bacteria and fungi to predatory invertebrates. Improving our ability to predict the capacity for soil to retain or release carbon requires a much better understanding of what these soil organisms do, individually and as a community. This presentation will report on the application of genetic and stable isotopic techniques to the study of two common soil invertebrate groups, enchytraeids and collembola, with different functional roles in soil C cycling. In Collembola, experiments designed to show the impact of Collembola on the fate of individual plant compounds will be reported, as will work on utilising the fatty acid compositions of Collembola as biomarkers for feeding behaviour. In enchytraeids, a replicated field experiment in Scotland, consisting of a series of common agricultural treatments (control, liming, biocide addition, nitrogen, liming+nitrogen), was used to assess the impact of these management strategies on enchytraeid community structure and C cycling. Molecular markers to identify enchytraeid species were developed, and pulses of ¹³CO₂ were used to introduce a stable isotopic label into the soil community via plants. The cholesterol content of individual enchytraeids was used to determine the ¹³C content of the worms; enchytraeid species incorporated differing amounts of ¹³C into their tissues, implying feeding preference differences. Liming was found to change enchytraeid species diversity, and the rate at which worms took up plant-derived ¹³C. Results of other groups of soil organisms will also be reported. Results indicate that feeding preferences are far more complex than widely accepted and that some groups of soil invertebrates gain significant amounts of C from newly-fixed photosynthate, but that this differs subtly between species.

Combined effects of *Azospirillum lipoferum* CRT1 inoculation and nitrogen concentrations on soil microarthropods and organic matter decomposition processes in maize agro-ecosystems

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An experiment was carried out in a maize field to assess the effects of the inoculation of the bacteria *A. lipoferum* CRT1 combined with three nitrogen concentrations (0, 70, and 130 kg N/ha) on different soil biological parameters: maize quality production, bacteria diversity, microarthropods, macrofauna and organic matter decomposition. The experiment was set up during three consecutive years on the same field using a randomized block (4 blocks) and plot (24 plots) design.

Microarthropods and organic matter decomposition assessment studies began the second cropping season and the experiment was repeated during 2 following years; each experiment was carried out during the maize growing season from April to October. Two methods were used for microarthropods: soil cores and litter-bags. Litter-bags were filled with the corresponding plot and block maize leaves cultivated and harvested the year before. Thus 6 different kinds of litter-bags were used each study year (*Azospirillum*/control, 3 nitrogen concentrations). Microarthropods colonisation of bags and maize decomposition were assessed during each cropping season by adding litter-bags on the top soil of each plot, between the rows, at the beginning of each cropping season (corresponding to maize seedling), and collecting them 3 times the first year and once the second year until harvesting. Microarthropods were then extracted from the bags using the Berlese method and maize Litter Mass Remaining (LMR) was evaluated using the Near Infrared Reflectance Spectrometry (Cortet et al., 2002). On the other hand, the first year, microarthropods were sampled by collecting soil cores and extracting microarthropods.

Results revealed few effects of the *A. lipoferum* CRT1 inoculation on microarthropods in soil cores and litter-bag colonisation dynamics, even though a significant effect was observed on soil bacteria communities. However a nitrogen effect was noticed on both microarthropod communities and maize decomposition, with a faster decomposition when nitrogen concentration increased. As no significant effect of the inoculation was observed on the agronomic parameters of the maize production, these results suggest that, in maize agro-ecosystems, microarthropods are more influenced by the quality of the litter and above vegetation than by the surrounding soil bacterial composition.

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Beyond protein: amino acids, earthworms and soils

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The availability of nitrogen (N) in soluble form that can be taken up by plants limits primary production in most terrestrial ecosystems. However, the majority of N in soils is organically combined and up to half of this is in the form of amino acids (AA). The free AA (FAA) are increasingly being recognised as an important part of the soil N pool, for both plants and the microbial population. It has been demonstrated that many plants can both take up and use intact FAA. This process occurs in plant species found over a wide range of habitats, and includes plants of agricultural importance. In some of these systems the FAA make up a significant part of the plant's N budget.

The efficiency of the decomposers is the principal regulator of the rate of return of nutrients from litter to soil, from where they can be taken up again by plants. Earthworms are keystone species because of the important role they play in many soil processes, particularly in decomposition and nutrient cycling. This is in no small part due to their high abundance and their widespread distribution. There is a large temporal and spatial variation in availability of FAA in soils, with a high turnover rate for individual FAA. We postulate that any systematic differences in FAA composition of soils are due to ongoing soil processes and earthworms will be a significant regulatory factor. There are indications that this is the case. In addition to their regulatory role, earthworms may serve as indicators for ecosystem health. They have been described as 'ecosystemivorous'; that is, they use soil and gut ecosystems as a source of essential AA. We hypothesise, then, that their AA profile may well reflect the soil habitat in which they live.

We use High Performance Liquid Chromatography to obtain the AA spectra from a number of earthworm species. Principal Components Analysis of these data show that their AA profiles differ. A significant amount of the observed variation is due to both the particular taxa involved (whether measured by species, or by feeding group), and also by the habitat or location that the individuals were collected from. Early indications are that other environmental variables (including various soil parameters) may also influence the earthworms' AA profiles. These data reinforce the idea that different earthworm species process the soil N differently. It also indicates that their ecosystemivorous nature makes them a suitable model for summarising the processes in each particular soil system.

Earthworm functioning in soils in relation to population density

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Ecological functioning of the earthworm *Lumbricus rubellus* was studied in laboratory microcosms. Manually fragmented leaf litter (*Alnus glutinosa*) was added on top of an unpolluted sandy loam soil. Earthworms were introduced after a week of preincubation in densities ranging from 0 – 10 per pot, and were incubated for 36 days. Soil organic matter, pH and other abiotic parameters were measured at the start as well as at the end of the experiment. The amount of litter disappearance was significant over time in all fragment size classes over 1 mm. A significantly larger reduction in weight was observed for 5-8 mm particles, suggesting preferential feeding. Litter weight loss was linearly related to animal density. Soil respiration was monitored every 2 hours throughout the experiment, and declined with time. This decline followed was described by linear regression. The control and high density treatment showed similar, rapid changes in time, suggesting optimal stimulation of microbial activity at intermediate densities. For our system the minimal decline rate was calculated to be at 4 worms. Soil organic matter increased during the experiments in the presence of animals, and was quadratically related to their density with a maximum at 7 worms per pot. Earthworm growth was linearly reduced with the logarithm of animal density. Loss of ignition of the remaining litter declined with animal density and could be described by a quadratic relationship, with an estimated maximum reduction at 9.7 individuals. The quantitative data from this study will be used to model earthworm functioning in polluted soils using a population dynamic approach (Klok & de Roos, 1998). The results of this study suggest that the contribution of earthworms to soil processes is not necessarily linear to their density, and that the quantitative impact of any population size is specific for the process involved.

Respiration rates of soil invertebrates from the temperate zone and from the tropics measured by infra-red gas analysis

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Release of CO₂ and other nutrients during mineralisation of plant litter in temperate and tropical ecosystems is mainly attributed to the activity of the soil microflora. It is also known that soil fauna feeding activity influences the microbial decomposition process. Measurements of the amount of CO₂ that is respired directly by soil invertebrates have been reported rarely so far.

To assess the direct contribution of the soil fauna to the carbon cycling a commercially available photosynthesis measuring system, based on infra-red gas analysis, was modified to measure the amount of carbon that is directly respired by small soil invertebrates.

Various soil invertebrates (e.g. millipedes, woodlice, earthworms) from the temperate zone (Germany), and from a tropical forest near Manaus, Amazonia, Brazil, were chosen for measurements and either collected in the field or taken from breeding cultures. Single animals or groups of 5-10 specimens were weighted and placed in a measuring cuvette that was continuously flushed with air in a closed circuit. During respiration measurements the relative humidity of the air in the closed system was in the range of 55 – 75% for termites and 80 – 95% for the other taxa. The temperature inside the cuvette was adjusted to 20 °C for temperate to 28 °C and 31°C for the tropical taxa.

Respiration rates of the tropical fauna were in the range of 26.8 – 994.6 μL CO₂ h⁻¹ g⁻¹ biomass fresh weight and were comparable to respiration rates of soil invertebrates from the temperate zone. The results indicate that biomass and respiration were not correlated and that the direct contribution of the soil fauna to the carbon flux via respiration is small as compared to the CO₂ released by soil micro-organisms.

The work reported here was performed at the laboratories of ECT Oekotoxikologie in Flörsheim, Germany and at the research station of the Empresa Brasileira de Pesquisa Agropecuária, Embrapa, located in the state of Amazonas (Brazil). It was part of the project “Soil Fauna and Litter Decomposition in Primary and Secondary Forest and a Mixed Culture System in Amazonia” carried out within the German-Brazilian scientific co-operation programme “Studies on Human Impact on Floodplains and Forests in the Tropics, SHIFT” (Höfer et al. 2001). The work was partly supported by the Brazilian (CNPq) and German (BMBF) government.

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Managing plant residues to improve soil fertility in central Amazonian agroecosystems. An integrated approach with agricultural trials, controlled field and laboratory experiments, ecotoxicological tests and a screening of eight different plantations with regard to soil macrofauna and decomposition

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The functional preconditions for a plant residue management in selected land use systems in central Amazonia were studied in a German-Brazilian SHIFT (Studies on Human Impact on Forests and Floodplains in the Tropics) project from October 2000 to September 2003. Objective was the development of recommendations for an optimization of a sustainable land use. In different plantations within the sites of Embrapa-Amazônia Ocidental (Manaus, Brazil) plant residues were managed to improve soil fertility, which we define as an integrative variable resulting from several measured variables like abundance of key macrofauna groups, soil organic matter (SOM) content, decomposition rates, C/N-ratio, cation exchange capacity, soil structure.

In two field experiments we treated plots in a rather degraded fruit tree plantation with different legume mulch quantities and qualities combined with different mineral fertilizer quantities and measured the effects on macrofauna, decomposition, soil organic matter, soil nutrient content and soil micromorphology. In a further field experiment woody residues were used as mulch material and two methods of land preparation as alternatives to slash-and-burn were studied. Complementary the functional importance of single factors and their interactions were tested in laboratory experiments with microcosms.

A field trial with three legume species planted to produce mulch material and a screening of eight different land use systems for soil macrofauna and decomposition rates were carried out to evaluate the transferability of the results of the controlled experiments.

Because pesticides are meanwhile increasingly used in Amazonia and the environmental risk is totally unknown to date, tests for their effects on soil macrofauna and decomposition processes under tropical conditions were also developed within the project.

The project was supported by the SHIFT-program “Studies on Human Impact on Forests and Floodplains in the Tropics” of the German Federal Ministry of Education and Research and the Brazilian National Council for Research CNPq, project IDs: BMBF/DLR: 01 LT 0014 and CNPq: 690018/00-2; run duration: Oct 2000 – Sept. 2003. Project leader: Dr. Hubert Höfer, contact: hubert.hoefers@smnk.de

Soil fauna affect crop nutrient and water use efficiency in semi-arid West Africa

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It has become increasingly recognized that soil fauna have a significant role in soil processes affecting nutrient availability and crop performance. A field experiment was conducted in southern Burkina Faso (West Africa) to investigate the contribution of soil fauna in nutrient availability and crop performance after application of different organic materials with contrasting quality. A split plot design with four replications was laid out. The main treatments were the use of pesticides to establish plots without fauna next to plots with fauna. The sub-treatments consisted in the application of *Andropogon* straw, maize straw, cattle dung, sheep dung, compost and a control. The results showed that soil fauna increased significantly crop nutrient and water use efficiency. Crop performance was significantly reduced in the absence of soil fauna. Crop nutrient use efficiency was highest with the use of easily decomposable organic material. Supplementing low quality organic material with nitrogen inputs is required to optimize the effects of their interaction with soil fauna on crop nutrient and water use efficiency in semi-arid West Africa.

Effects of earthworms and enchytraeids on nutrient mobilisation after flooding of wetland soils

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Periodically flooded wetland soils are important ecosystems, functioning both as mediators of water flow and as habitats for a number of specialised organisms. Many birds prefer such meadows as breeding places, due to the large number of easily accessible prey invertebrates. Among them, earthworms and enchytraeids usually constitute a major percentage of the biomass. Soil fauna, in particular oligochaetes, are known to have a large, mostly indirect, impact on nutrient turnover. To our knowledge, thus far all studies dealing with the effects of earthworms on nutrient mineralisation or retention were restricted to soils from grassland, arable land or forests. Information on wetland soils that are periodically flooded is missing. Moreover, very little is known about the nutrient exchange between the aquatic and terrestrial compartments in such ecosystems. Aim of our study was to shed some light on the possible role of oligochaetes in the mobilisation or retention of nutrients from soils after a flooding event. We hypothesised (i) oligochaetes will increase N mineralisation and (ii) decrease P mobilisation, (iii) enchytraeids and earthworms will differ in their effects on nutrient turnover, (iv) effects of oligochaetes on nutrient turnover will vary with site conditions.

We conducted a laboratory experiment with soils from three different flooded grassland sites, a peat soil from a nature Reserve (river "Wümme"), a marsh soil (river "Ochtum") and a gley soil subject to contamination (river "Elbe"). The soils were defaunated by deep-freezing and then re-inoculated with the dominant oligochaetes from every site. These were *Lumbricus rubellus* for marsh and gley soil, *Octolasion cyaneum* for peat soil, and "black-box communities" of enchytraeids, extracted from each site and identified in the end of the experiment. The soil cores (8 cm diameter, 6 cm deep, 5 replicates each) were placed in plastic containers and supplied with either 3 earthworms, 30 enchytraeids, 3 earthworms + 30 enchytraeids or left unsupplied (control) and then flooded with the respective river water for three days. Temperature, pH and oxygen saturation of the water were measured daily, nutrient concentrations in the end of the experiment.

After three days, only 3-4 % of the supplied enchytraeids were found, suggesting high mortality. All *O. cyaneum* had survived, yet only about 50 % of *L. rubellus*. pH and O₂ decreased during the course of the experiment, the decrease being lowest in the flooding water on Elbe soil. Generally, nutrient concentrations in the flooding water differed between soil types, and so did the effects of the animals. In the peat soil, *O. cyaneum* alone and in combination with enchytraeids significantly increased phosphate concentration. Ammonia concentration was positively affected only by earthworms alone. A combination of earthworms and enchytraeids increased phosphate and nitrate concentrations in the marsh soil. In the gley soil, in the combined treatment nitrite concentrations were higher than in the control soil. In treatments with enchytraeids, in the peat soil ammonia and pH were highly positively correlated, hinting at a significant role of the animals in stimulating microbial activity.

In conclusion, also in periodically flooded soils fauna play an important role in nutrient turnover: in the soils studied, their presence had either no effect or stimulated nutrient mobilisation after flooding. These laboratory-based data should be studied with more soils and under field conditions: if our results should be confirmed, it might be necessary to reconsider water management of wetland soils with a large oligochaete biomass (i.e. with a high mobilisation potential) in order to avoid undesired effects on river eutrophication.

Dynamics of nitrogen and phosphorus influence on *Cognettia sphagnetorum* in mor-humus during a two-month experiment

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Nitrogen mineral compounds applied as fertilizers in coniferous forests deplete often enchytraeid populations. Phosphorus as the element managing nitrogen turnover could modify nitrogen impact. This hypothesis was checked in a two-factor experiment designed according the orthogonal design.

The design included 9 alternatives with applying of urea as a nitrogen compound and sodium pyrophosphate as a phosphorus one. Defaunated mor-humus (after three days freezing at -21°C) was prepared as an experimental substrate and distributed in experimental jars. The compounds applied in 3 concentrations: 0, 2.5 and 5 mg of urea and 0, 1.7 and 3.4 of phosphate per 1 g of substrate (dwt). To moderate sodium influence disodium carbonate in equivalent concentrations was added in corresponding jars. The substrate without any chemicals was used as absolute reference. Every experimental alternative was triplicate and total number of experimental jars was 180. Fifty enchytraeids *C.sphagnetorum* extracted before the experiment were added to every jar and animals from selected jars were extracted after 1, 2, 3, 4, 6 and 8 weeks. The jars were kept at 15°C in a climate chamber. Enchytraeid number per a jar and a ratio (%) between the number in an experimental jar and the absolute reference ones were used as endpoints to estimate effects of the chemicals on enchytraeids.

Enchytraeid number comprised 60-80% of initial ones during the first month of the experiment. Urea influenced positively the number after 1 week, and phosphate — after two weeks of the experiment. The number reached the initial one after 1.5 months of the experiment but urea impact became negative. Phosphate positive impact was significant after two months of the experiment but urea was reducing the effect. Regression models explained 23-40% of the number fluctuations in the experiment and confirmed the effects of the chemicals.

Relative (to absolute reference) number was higher than 100% in experimental variants during the first month of experiment, excluding the 2nd week. Urea impact was positive during the 1st week and phosphate – during three weeks. Influence of the applied chemicals was negligible after the month but increased sharply to 1.5 month nonetheless that the relative number decreased. The number returned to 100% to the end of the experiment.

Dynamics of the chemical impact on enchytraeid number connected probably with changes in food resource not direct effects of the chemicals on enchytraeids. Periodic fluctuations of urea and phosphate influence on the animals were not an artifact but reflected perhaps the utilization of compounds by microorganisms fed by enchytraeids. Further research should confirm or reject the hypothesis.

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Linking biodiversity and nutrient retention: effects of management strategies on below-ground biodiversity and nitrogen dynamics

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Nutrient retention is an important management objective in agriculture. Soil organisms play a key role in nutrient cycling, and the below-ground biomass and biodiversity may therefore be an important factor determining nitrogen dynamics. Still the effect of management practices in agricultural systems on below-ground biomass and biodiversity is hardly known. The aim of our study was to identify key factors that determine the biomass and biodiversity in agricultural soil and determine their relationship with nitrogen dynamics. We set up a four-year field experiment on fields with a history of low soil biodiversity (i.e. conventionally managed arable land), and high soil biodiversity (i.e. extensively managed grassland).

We studied the effects of conversion of the grassland to arable land and establishment of grassland on the arable land, on soil biological and nutrient parameters. These conversions were compared with control treatments, being long-term arable land and long-term grassland. Furthermore, we studied the effect of different management strategies ranging from highly intensive (monoculture, no cover crops, herbicide application, 20 cm tillage, complete fertilisation) to a very extensive (rotation, cover crop, mechanical weed management, 10 cm tillage, reduced fertilisation) soil and crop management.

The arable systems had a smaller, but also different faunal community than the formerly grassland system. Conversion of grassland to arable land led to strong decreases in the biomass and diversity of the soil fauna to levels that were lower than found in the long-term arable land. Soil microfaunal groups and bacteria were better capable of responding to the new circumstances than macro- and mesofaunal groups, probably due to higher resistance to disturbance and colonisation ability. Conversion of arable land to extensively managed grassland led to an increased biomass of soil macrofauna, but the diversity of these groups did not yet increase. The soil microfauna and bacteria were less clearly affected by the changes. Nutrient retention was highest in the grassland systems and lowest in the arable fields on former grassland. Nitrogen dynamics appeared to be strongly related to bacterial biomass and organic matter content, whereas the relationship with soil faunal biomass and diversity was less evident. Therefore, in our fields nitrogen dynamics were probably mainly determined by soil characteristics other than the soil faunal diversity.

How Collembola decrease the nitrogen uptake of maize through arbuscular mycorrhiza?

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Springtails have different effects on the structure of the arbuscular mycorrhizal (AM) fungi. The effect may be advantageous or disadvantageous for mycorrhiza growth and development. However, there is little information on how AM fungi functions are influenced by Collembola. In this experiment the question was addressed whether high density of Collembola may decrease the nitrogen uptake of maize plant.

A microcosm experiment was set up on the field. The microcosms were separated by a fine sieve of 42 µm mesh size into two parts. Microcosms were filled up with brown forest soil previously air-dried in order to eliminate meso- and macrofauna. A pre-germinated maize seedling was planted in one part of the microcosms. A mycorrhizal inoculum of *Glomus mosseae* and *Gigaspora rosea* was propagated onto soil. ¹⁵N marked ammonium sulphate was applied in a distance of 15 cm from the seed (with or without Collembola) in the other part of the microcosms or immediately to the root of the plants (without Collembola). Mycorrhiza was allowed to grow for six weeks. Thereafter the Collembola *Sinella coeca* was put in the maize free compartment of the microcosms in a density of 0.6 animal g⁻¹ soil for two weeks. Microcosms were destructively sampled at the end of the experiment.

The N % and ¹⁵N% uptake through the root and AM were greater than only through the AM without Collembola. Collembola activity did not influence total plant biomass, shoot biomass, root biomass, shoot/root ratio, plant water content, soil CO₂ production. On the other hand hyphal length, N% and ¹⁵N% of the maize seeds were significantly decreased due to presence of *S. coeca*.

Results of the experiments show that a hyphal network was able to get established in six weeks in the microcosms. Maize seeds took up nitrogen by mycorrhiza from a source in a distance of 15 cm. Collembola destructed hyphal network as it is proved by decreased hyphal length. As a consequence, nitrogen uptake (total and marked as well) of plants decreased significantly. It was demonstrated that the Collembola are able to influence the N uptake of the plant through arbuscular mycorrhiza.

Microbial biomass dynamics under a *Tamarix aphylla* tree in a sandy desert soil

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The desert habitat is characterized by a combination of extreme abiotic conditions, and low amounts of available water, nutrients, and organic matter. Water and organic matter availability is the major factor limiting primary production and determining soil biota activity. As a result, soil biological activity will be strongly affected in time and space (vertical distribution).

Since sandy soil in a desert environment is characterized by fast water infiltration, moisture availability at a deeper layer will be affected by the amount and intensity of rainfall. Moreover, plant ecophysiological adaptation will strongly influence abiotic conditions in the soil beneath the plants. *Tamarix aphylla* is known to be one of the most common adaptations developed by plants, exhibiting a mechanism for secretion of excess salts as aggregates through their leaves. These salt aggregates fall down together with their leaves on the soil surface, creating "Islands of Salinity" beneath the *T. aphylla* plant. As a result, soil biotic components are exposed at this niche to extreme abiotic stress conditions.

Our goal was to understand the effect of *T. aphylla* on the dynamics of soil moisture availability, organic matter, soil microbial biomass, and the changes in bacteria and fungi biomass on a spatial and temporal scale.

Soil samples were randomly taken beneath and between plants from the 0-50 cm layer at 10 cm intervals, and analyzed for moisture and organic content, CO₂ evolution, and microbial biomass.

Preliminary results showed a clear trend regarding the vertical distribution of soil moisture and organic matter, where the highest amount was found in the upper 0-10 cm layer with a gradual decrease toward the deeper layers. Based on preliminary results, soil microbial biomass and CO₂ elevation was found to be strongly affected by seasonality, where rainfall events caused a significant increase in biotic variables in comparison to the dry summer season.

The results of this study demonstrate the importance of moisture and organic matter availability and the "Salinity Island" effect on the ecophysiological status of the microbial community in a sandy desert system.

Biodiversity and ecosystem services – a novel experimental approach using earthworms

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Central to resolving current controversies in biodiversity/function research is an appreciation that experimental design may confound the determination of the contribution of different facets of biodiversity. The separate effects of richness and evenness and the manner in which they interrelate to affect function have not been addressed. Importantly, most experiments have used replacement designs which have been criticised for containing confounded species density treatments and size-bias. Here we examine the relationships between earthworm functional group diversity and community and nutrient dynamics in an experiment whose structure is based on the simplex design.

Simplex designs to investigate the factors affecting change in community structure are best examined in assemblages all of which contain all species, whereas designs containing monoculture and mixed assemblages are of use in questions on community function. Since the investigation addressed questions of both structure and function a compromise simplex design was used. A simplex design at a single level of initial abundance is a multidimensional Replacement Series Design and is subject to the difficulties attendant on such designs. Hence, for a complete design the assemblages were repeated at a second level of overall initial abundance and at two levels of resource availability.

Results show synergisms between earthworm functional groups in terms of worm survivorship, nitrogen dynamics and the existence of complimentary effects on microbial function.

Organic matter breakdown rates along an urbanization gradient

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The growing need for accessibility to urban employment has meant that South African cities have witnessed an unprecedented increase in the number of squatting and informal settlements on the urban fringe. Informal settlements, together with trends of sub-urbanization have resulted in the fragmentation and sprawling of the city, this in turn increases strain on the natural environment. Urban environments have profound effects on soil physical and chemical properties inducing soil profile modifications. Understanding these changes in soil properties is important since changes can lead to responses in soil community structure and alteration of ecosystem processes such as organic matter (OM) breakdown. With this study we aim to: (1) evaluate the bait-lamina - and litter bag methods to determine OM breakdown and to develop a system representative of a grassland habitat and (2) determine the effects of urbanization and anthropogenic activity, if any, on OM breakdown rates, using an urbanization gradient approach. This investigation forms part of a larger study with in the urban environments in the Grassland Biome of South Africa.

Relationship between soil macro-invertebrate biomass and litter nutrients in different types of vegetation in Peruvian Amazonia

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A positive and strong relationship was found between the density and biomass of macro-invertebrates and litter mass in policulture systems in central Amazonia (Vohland & Schroth, 1999); it was also shown that isopods and diplopods are key-decomposers and have significant and strong relationships with phosphorus concentrations in litter in agroforestry systems (Tapia-Coral, 1998). The present work aimed to find a relationship between the macro-invertebrate biomass, collected by the TSBF method, and the carbon and nutrients stocks in the litter of primary forest, secondary forest (16 years-old), and forest plantations of *Cedrelinga catenaeformis* and *Simarouba amara* (15 and 16 years-old, respectively). The study was carried out at the "Jenaro Herrera Research Station" of the "Peruvian Amazonia Research Institute" (IIAP), located 200 km above the city of Iquitos, on the right margin of the Ucayali river (73°40'O and 4°54'S, Loreto -Peru). Annual precipitation is 2674 mm and the monthly medium temperature is 26°C. The most abundant macro-invertebrates in primary forest were (2482 ind.m⁻²), while in forest plantations, were the (3702 ind.m⁻²). There was punctual evidence of relationships (positive and negatives) for some selected groups of macro-invertebrates, such as ants and two of the most important groups of terrestrial detritivores in areas cultivated with arboreal species: diplopods and isopods. In the primary forest, the ants showed a positive relationship with total litter mass and its phosphorus and calcium stocks; the isopods presented a positive relationship with the C:N and N:P ratio in the litter. In the *C. catenaeformis* forest plantation, diplopods had a positive relationship with woody mass, with carbon, nitrogen, potassium and calcium stocks and with exchangeable bases; isopods were positively related with the stocks of calcium of and exchangeable bases. In the *S. amara* forest plantation, only beetles presented a significant relationship (negative) with the C:N ratio; in secondary forest, ants had a positive relationship with the C:N ratio. Thus, ants, diplopods and isopods are considered important decomposers of litter, involved in the carbon and nutrients release in natural and managed systems, where they participate directly in the dynamics of organic matter and nutrient release (Lavelle *et al.*, 2003), and litter produced by planted trees is a fundamental determinant for the growth of forest plantations.

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Effects of temperature regime on respiratory activity in two species of litter earthworms

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Predictions of consequences of global climatic changes for soil systems require knowledge of effects of thermal instability on key species of soil communities, such as earthworms. Variation of earthworm respiration with temperature (especially its diurnal fluctuations), developmental stage and population density is still little studied.

Rates of CO₂ production in cocoons, juveniles and matures of *Lumbricus rubellus* were measured at constant (2, 5, 10, 15, 20°C) and diurnally fluctuating temperature regimes (0-10, 5-15, 10-20°C) covering the whole range of temperature conditions experienced by this species in forests of Central Germany. For matures, measurements were made both on single specimens and earthworm pairs. Respiration of mature *Dendrobaena octaedra* was measured on single animals and groups of three worms, at constant 15°C and diurnally fluctuating regimes of 10-20 and 5-25°C.

In *L. rubellus*, both temperature level and temperature regime (constant vs fluctuating) were important determinants of the respiratory activity. Respiration rates significantly increased with temperature at both constant and fluctuating regimes. Respiration rates and patterns of temperature responses varied between developmental stages (cocoons, immatures, adults). Generally, rates at fluctuating regimes exceeded those at constant regimes in all the stages studied. This suggests that at diurnally fluctuating temperature earthworms allocate more energy resources to respiratory metabolism. The comparison with literature data suggests that litter earthworm species, such as *L. rubellus*, are more responsive to changes in temperature than soil dwelling species, such as *Aporrectodea rosea*.

In *L. rubellus*, which reproduces sexually and needs contacts with conspecifics for sperm exchange, respiration rates at constant and fluctuating regimes did not differ between individuals and two-individual groups. In contrast, in the parthenogenetic *D. octaedra* both respiration rates and offspring production were significantly lower in earthworms kept in groups as compared to specimens kept individually. This pattern of offspring production is characteristic for remote European populations of *D. octaedra* (Uvarov 1995: Eur.J.Soil Biol. 32,2:111-118) and may be regarded as a general feature of the species.

Respiratory metabolism of *D. octaedra* and *L. rubellus* fundamentally differs despite both species colonise similar soil layers and frequently co-occur. Within the temperature range of a mid-European growing season, respiration rates of *D. octaedra* are markedly higher, metabolic adaptation is absent (nearly constant Q₁₀ values), metabolic rates and reproduction are negatively affected by density. In contrast, *L. rubellus* appears to be capable of metabolic compensation, in particular within its optimum temperature range, responds little to increased density of conspecifics and allocates more energy to respiration at daily fluctuating compared to constant temperature regimes. These differences have major implications for life history strategies, energy balance of individuals and populations and interspecific interactions between the two species.

Effects of slurry application method on soil fauna communities and nitrogen mineralisation in permanent grassland

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In the VEL & VANLA nutrient project farmers want to limit the external inputs of nitrogen (fertilizer) to their soils and want to maximize nutrient uptake from manure slurry. Also, to limit nutrient losses they produce a manure slurry with a lower N_{mineral} to N_{organic} ratio. Decomposition of manure and mineralization of nitrogen from organic material present in the manure are biological processes and are therefore dependent on the presence of a well-developed soil life. Many farmers are convinced that slit injection harms soil life. According to them, Dutch legislation that requires farmers to inject manure slurry, conflicts with the development of a healthy soil life community.

At an experimental field, effects of slit injection on certain soil animals, namely earthworms, enchytraeids and nematodes were investigated in the spring of 2002 and the summer of 2003. Firstly, effects of slit injection were compared with spreading of the manure slurry aboveground. Secondly, effects of cutting the slit and presence/absence of manure slurry were studied within the slit injection treatment. No effects of slit injection on population numbers of enchytraeids were found. Within the nematode community slit injection caused an increase in the relative fraction of 'enrichment opportunistic species' (indicators of nutrient enrichment) compared to the treatment spreading of manure slurry aboveground. Cutting a slit in the grass sod resulted in a decrease in the number of endoparasitic plant feeding nematodes in the soil. Apparently, cutting the slit affected grass development, resulting in a movement of free-living endoparasitic plant feeding nematodes into the grass roots. Slit injection resulted in a significant decrease of total earthworm numbers in certain treatments. However, these effects were only significant in the wet spring of 2002. In the summer of 2003, under very dry weather conditions, earthworm abundances were low and most of the found earthworms were inactive. Manure slurry negatively affected earthworms that live at the soil surface (epigeic worms). Especially the fraction of juvenile *Lumbricus rubellus* earthworms decreased significantly after the spreading of manure slurry (independent of placement). The results of the performed study reveal more subtle effects of slit injection on earthworms than an earlier study by De Goede et al. (2003). De Goede et al (2003) found no clear effects of manure application method on earthworm numbers. However, they did find that in a system with slit injection less epigeic and more endogeic earthworms were present. Consequences for the nitrogen mineralisation due to changes in soil fauna in these systems will be discussed.

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SESSION 4

Ecosystem Engineering by Soil Fauna

ORAL CONTRIBUTIONS

Coupling spatial variations in earthworm density and soil structure, a modelling approach

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It is known that the repartition of soil fauna is heterogeneous. In particular, earthworms have often a patchy distribution. This distribution is partially linked to soil heterogeneity and it may be obviously hypothesized that earthworms are more numerous in favourable patches, for example where soil is more humid and where soil organic content is higher. However, statistical analyses testing for the effect of soil characteristics on earthworm density often only explain a low percentage of the variability. An alternative and complementary explanation to the heterogeneity of earthworm spatial distribution is that it is highly influenced by earthworm own dynamics and not only driven by external environmental factors: i.e. there is some auto-organisation.

We tested this hypothesis using a simulation model based on the life cycle of *Millsonia anomala* studied at the Lamto field station in Ivory Coast. It is an andogeous earthworm which tends to compact soil: it only ingests small soil aggregates and its casts form larger aggregates which cannot be reingested until they have been weathered or ingested by decompacting earthworms such as eudrilidae. Therefore, if there is a high density of *M. anomala* locally, soil should be transformed into macroaggregates which should be detrimental for the dynamics of the earthworm species, i.e. there should be a local regulation loop. The only link between different local patches (for example 1 square meter areas) is the mobility of earthworms which is *a priori* very low.

The model is a discrete spatial model: space is divided in one-meter wide cells and the density of earthworms is tracked in each square of a 50 m X 50 m plot. The density of earthworms taken into account is considered to be the density during the rainy season and is modified at each time step, i.e. each year. Only one source of soil heterogeneity, the % percentage of soil that is compacted, is considered. *M. anomala* life-cycle is modelled using a reproduction rate (\hat{a} , number of newborn offspring produced each year) and a minimum mortality rate (\hat{a}_{min}) corresponding to the survival rate of individuals placed in perfect environmental conditions. This mortality rate increases when the local density of earthworm increases (through an exponent \hat{a}). Dispersion is modelled using a normal distribution, the higher is its standard deviation (\hat{o}) the more likely is long-distance dispersal. All parameters but \hat{a} and \hat{o} were estimated using published results.

Extensive simulations show that patchy realistic distributions appear when dispersal is very low (\hat{o}) and when mortality is very sensitive (\hat{a}) to the local density of earthworm and the percentage of soil transformed into macroaggregates. Thus, our model provides an indirect hint on the low dispersion ability of earthworm and a factor regulating their dynamics. New experiments should be designed to tests thoroughly for these hypotheses. The model can also be used to test for the influence of earthworm life-cycle parameters on parameters relevant at the ecosystem scales, for example the mean soil structure and its consequences on the mineralization of soil organic matter.

White grubs as agricultural pests and as ecosystem engineers

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The family Melolonthidae (Scarabaeoidea) can be divided into six subfamilies, and in Brazil, the most common larvae living in soils in agroecosystems are of the Rutelinae (e.g., *Anomala* spp.) and Dynastinae (e.g., *Cyclocephala* and *Bothynus* spp.) subfamilies, that feed on OM and rarely on roots and of the Melolonthinae subfamily (e.g., *Phyllophaga*, *Diloboderus* spp.), that feed mostly on roots and less on OM. The objective of this study was evaluate the role of Melolonthidae in agroecosystems, where the density of melolonthid larvae in soils can range from a few to >100 individuals m⁻². Larvae can vary from less than 1cm, at first instars up to 7cm at the final (3rd) instar. Melolonthid larvae consume from 45 to 80 times their own weight during their development (Móron 1987). *Phyllophaga cuyabana* in the 3rd instar, feeding on soybean roots, weigh on average 0.8 to 1g and can consume >30 times their biomass, returning about 16 to 20% to the soil as faeces . In soybean production systems in Brazil, rhizophagous larvae generally tend to become pests in situations where soil biodiversity is reduced, favoring the predominance and population increase of rhizophages, and when the larger individuals (3rd instar) occur in synchrony with the most susceptible plant stages. Furthermore, environmental conditions can also reduce plant tolerance to rhizophagy, or cause the facultatively phytophagous larvae to move from saprophagy to rhizophagy.

Obbligatory (e.g., *Bothynus* spp.) and facultatively (e.g., *Diloboderus* spp.) saprophagous species are typically more abundant in no-tillage agroecosystems, where the larvae construct vertical tunnels in the soil (galleries up to 3 cm wide), connected to the soil surface when they are actively feeding. In samples taken in soybean in Londrina-PR we observed that the total volume of the holes opened by the beetles and/or larvae per surface area (m²), was almost 10 times greater in no-tillage than conventional tillage. On the other hand, population fluctuation of the rhizophagous *P. cuyabana* was similar in both no- and conventional-tillage, although rhizophagous larvae also open tunnels (temporary) in the soil, generally for locomotion (searching for food) and pupation. Tunnels of saprophagous species can be abundant (>70 m⁻²) and >1 m deep. Some species bury large amounts of plant litter, contributing to its decomposition and mineralization, significantly increasing P, K and OM content of the galleries compared with adjacent soil (Gassen 1993). These biopores also increase soil porosity and aeration, improve drainage, serve as pathways for root growth and as refuge for many other invertebrates. However, in cases where large saprophagous larvae populations are present, most of the surface litter is rapidly incorporated, reducing available resources for other saprophagous organisms (e.g., millipedes, earthworms), possibly reducing their abundance by competition. In sum, due to their physical effects on soils and the induced changes to resource availability in the soil ecosystem, white grubs should be considered as ecosystem engineers.

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The impact of termite sheetings age on their fungal communities

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In previous study we have shown both quantitative and qualitative modifications of soil fungal communities in termite sheetings. However, mechanisms involved in building of sheetings and by which these modifications occur remain unknown. In this work we described the succession of fungal communities in the sheetings of three fungus-growing termite species by combining cultivation techniques and culture-independent methods including DNA extraction, PCR and denaturing gradient gel electrophoresis (DGGE). We also estimated the abundance of fungi by using plate-count technique and ergosterol determination. The fungal communities of these sheetings were sampled at different ages.

The functional potential of fungal communities was assessed by their capabilities of degrading different substrates including proteins, polysaccharides and tannins. The results of this study showed significant differences between the fungal communities of termite sheetings and those of surrounding soil. These differences were observed at quantitative, qualitative and functional level as well and were marked particularly in the fresh sheetings of termites. The characteristics of fungal communities of the surrounding soil were quite similar with those observed in the old sheetings of termites. These results highlight that these original fungal populations are present at early stage on the fresh structures and thus do not colonize them progressively as one could suppose it.

Spatio-temporal dynamics of physico-chemical properties in the biostructures produced by soil ecosystem engineers: a synchronical approach in Neotropical savannas

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By definition “ecosystem engineers” are those organisms capable to modify physically the environment in which they live. The engineer organisms do so by producing “biogenic” structures or biostructures (BS) that has an impact on soil processes and affect the spatial and trophic resources for one, or generally more, organisms. Large macroinvertebrates produce BS on the soil surface and in the soil. These structures have varying characteristics according to the species and the soil where they carry their activities. However we suffer from a lack of studies dealing with a description and characterization of the BS produced by these invertebrates, e.g. earthworms, termites, and ants. To assess the contribution of soil biota to ecological processes and ecosystem function a previous step is to describe the phenomena that occur in their BS. The characterization of their morphology, size, and assessment of their abundance, spatial distribution, and physico-chemical properties of BS are needed to understand and evaluate their indirect effects in the environment at a given scale.

The study site was located in the well-drained isohyperthermic savannas of the Eastern Plains of Colombia, at the Carimagua Research Station (CIAT-CORPOICA), 320 km East Villavicencio. The area is characterized by open herbaceous savannas and gallery forests. We determined total C (mg g dry soil⁻¹) and NH₄⁺ and NO₃⁻ contents (µg g dry soil⁻¹) in the BS produced by several species of termites (subfamilies Termitinae and Nasutitermitinae) and ants (Myrmicinae) in a Trachypogon savanna and a gallery forest. We sampled from the center of the biogenic structure to the edge at proportional distances, i.e. 0, 20, 40, 60, 80 and 100% for large BS and 0, 50, 100% for small BS. Control soil was taken aside 1 m apart from the BS by using a small metal cylinder (Ø 5 cm x 8 cm depth) to sample at 0-5 and 5-10 cm depth and was used for comparisons. There were significant differences between all variables measured (ANOVA).

Organic matter contents were lowest in the BS structures produced by ants, especially those deposited by *Trachymyrmex* sp., and even those produced by *Atta laevigata* from the gallery forest. The highest contents were found in the BS produce by *Nasutitermes* sp1 in the gallery forest. NH₄⁺ contents were higher in the BS produced by the termite *Spinitermes* and no significant differences were found between those BS from the savanna and those from the introduced pasture. The highest NH₄⁺ contents were obtained in the arboreal BS produced by Nasutitermitinae sp2 in the gallery forest. Regarding NO₃⁻ the highest values were found in the BS produced by *Nasutitermes* sp1 and *Nasutitermes* sp2 from the gallery forest; in general these values were ten times higher (above 1,000 µg g dry soil⁻¹) than those obtained for the rest of BS. The ecological significance of these differences is also discussed.

Control of a forest ecosystem by the periodical train millipede, *Parafontaria laminata*

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Soil macrofauna such as earthworms and termites are called ecosystem engineers. Many studies on their ecological functions have been done so far, however there are very few studies on the macrofaunal effects on forest plant growth in a field condition. The train millipede, *Parafontaria laminata* (Attems) is known for their swarming of huge number of adults in an exact 8 year cycle in central part of Japan. Length of the cycle is fixed by their life history; 7 years to be adults and only adults swarm on the forest floor, and only one cohort exists in one site. Since we could observe very high biomass of the millipede, we hypothesised that the adult population impacted forest ecosystem by acceleration of decomposition, thus periodical changes in plant growth could be observed.

We measured tree and shrub growth, litterfall, organic matter accumulation on the forest floor, and soil fauna, since 1997, and also observed soil aggregates distribution, since 2001. In a field microcosm, we manipulated the millipede densities when the millipedes were at 6th, 7th and adult stages. Sample trees were collected for tree ring analysis.

Adults emerged on September 2000, and after overwintering they reproduced and all the adults died by August 2001. The study site with the highest density showed extremely high density (max. 311 m⁻²) and biomass (28.6 g dry wt. m⁻²) of the adult millipedes. Population density was highest at the 1st instar, however total biomass per area was highest at the adults. 7th instar larvae and adults came appear on the forest floor and exploited both organic layer and mineral soil, whereas juveniles younger than 6th instars seemed to eat only mineral soil, since the juveniles were found only in the mineral soil layer. The observed active feeding on mineral soil and litter by the millipede 7th instars and adults increased larger soil aggregates and carbon contents in the soil, and they also increased nitrogen mineralization in the field microcosms. Nitrogen contents in leaf litterfall of larch were higher in the sites with high millipede density, during 1999 to 2001. These results suggest that nutrient availability for larch could have been improved at the time of adult millipede emergence in 1999 to 2001. The annual tree growth was better around 2000, and a reduction of growth was observed after 2002. Tree ring analysis for longer term revealed a cyclic growth pattern at high millipede density site.

Ecological factor responsible for the changes in tree growth in the train millipede soil seem to be a promotion of nutrient availability by the millipede feeding on litter and soil at the time of the final larval instar and adult stage. Due the small biomass of younger generation, the effects of nutrient enhancement become smaller after the adult emergence year. Thus at the train millipede soil, larch shows cycling growth pattern. This study clearly showed a field evidence that soil macrofauna controls tree growth.

Mound building ants as ecosystem engineers in dry grasslands: belowground effects on soil fauna and plant growth

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Ants are able to directly or indirectly modulate the resource supply to other species by altering the physical and chemical environment and affecting soil organisms and plants. The subterranean ant *Lasius flavus* (Fabr.) plays an important role as soil engineer and therefore modulates the whole food web by causing distinctive differences in biotic and abiotic soil conditions. However, little is known about its direct effects on the structure of soil animal communities.

To evaluate this role of ants as ecosystem engineers the effect of yellow ants (*Lasius flavus*) on nutrient content, microbial activity, soil fauna and soil fertility was studied in a dry grassland on limestone. Nest mound substrate was sampled during spring and summer and was compared to substrate away from mounds in a factorial design. The modification of the microhabitats in the mounds of the subterranean ants strongly affected soil conditions and also soil animals and microorganisms. Nest mound soil had significantly higher available phosphorus and nitrogen levels than the surrounding soil. In the mounds total soil N was significantly increased whereas total soil C was significantly decreased. Substrate moisture and pH did not differ between mounds and controls, but in the mounds the temporal fluctuations in moisture content were considerably more pronounced than in the surrounding soil. Microbial biomass, microbial respiration and nematode density fluctuated, but overall were significantly increased in ant mounds.

An outdoor bioassay experiment using different plant species growing in mesocosms which were permeable to ants and were placed in and beside ant hills indicated that the distinctive differences in biotic and abiotic soil conditions caused by ants strongly affect the structure of the soil invertebrate community and root growth. The densities of spiders and oribatid mites were reduced in the mesocosms incubated inside ant hills, whereas the densities of plant lice and elaterid larvae, total mites, the microbial biomass and biomass of plant roots increased in the high ant density treatments.

It is concluded that the subterranean ant *Lasius flavus* plays an important role as soil engineer and therefore modulates bottom-up forces for the whole food web by altering the resource supply to other species. But they also directly affect belowground populations of different trophic levels including plants, by top-down control via predation, interference and disturbance, and tending species of aphids and coccids.

SESSION 4

Ecosystem Engineering by Soil Fauna

POSTER CONTRIBUTIONS

Impact of the termite mounds (*Macrotermes subhyalinus*) on the metabolic diversity of microbial communities in soils

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The beneficial role of termites on the physical and chemical structure of the tropical agrarian systems has already been established for several years. However, their beneficial or depressive influence on the activity of the telluric microorganisms has not been yet fully studied.

In order to carry out such a research, we ran a microbiological study calling upon several techniques : culture on solid medium, phenotypic and microscopic identification, Biolog, followed mineralization of carbon and nitrogen, as well as with physicochemical characterisation of termites nests of *Macrotermes subhyalinus* and their peripheries (up to 1 m) compared to control soils (20 m away) at the Bossoum village in Northern Cameroun.

The obtained results showed that the contents of clays, fine silts, carbon, nitrogen, exchangeable bases and the pH are higher on termitic soils compared to the control soils. The enumeration of bacteria and fungus showed that the bacterial density is more significant than that of fungus of all the samples and than these densities are higher on termitic soils compared to control soils.

Microscopic observation and metabolic profile studies showed a greater diversity in the composition of the microbial communities in the termitic soils compared to control soils. This diversity is more significant in the old nests.

Finally, followed mineralization of carbon and nitrogen proved that the difference observed at the community level of the various samples are synonymous with differences on the level of the biogeochemical transformations which proceed there.

Phosphatase activities and metabolic diversity of microorganisms in soil-feeding termite nests and tropical rainforest soils

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The microbicidal activity of the earthworm gut extracts

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It is widely accepted that earthworms selectively modify biomass (Schönholzer et al., 1999) and species composition (Tret'yakova et al., 1996) of soil microorganisms by gut passage effects. The mechanisms of such selection have not been revealed. We hypothesized that earthworm digestive tracts possess killing activity towards microorganisms as it was demonstrated for soil millipedes (Byzov et al., 1997).

Gut extracts of the earthworms *Eisenia fetida*, *Lumbricus terrestris* and *Aporrectodea caliginosa* were obtained. The earthworms were kept on sterile sand for several days to clean up the digestive tracts. Then the worms were desiccated on a freezing table (-16°C). The cleaned digestive tracts were cut into pieces and then the foregut and hindgut parts were centrifuged at 12,000 rpm for 10-15 min to sediment gut tissue, blood cells and the majority of microbial cells. One portion of the fluid was heated at 98°C for 10 min to inactivate proteins and then it was centrifuged. Both the native fluid and the supernatant were then used for microbiological test. Bacterial suspensions were mixed with the fluids (3 µl, 1:1 v/v) and the drops were placed on a thin nutrient-agar film. The CFU numbers were estimated under microscope after 12-24 hours of incubation. It was found that the digestive fluids of the worms exhibit selective killing activities towards some bacteria and yeasts. The gut extracts from the foreguts were most active than that of the hindguts. The sensitivities of bacterial strains to the digestion differed. The CFU numbers of the most sensitive microbes decreased 100 times after 20-30 min of incubation the others survived the incubation. In *E. fetida* the pre-heated fluid showed the killing activity indicating that compounds other than proteins are involved in the digestive process.

This mechanism is proposed to explain selective effects of earthworms on microbial populations in soil.

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Changes of earthworm-influenced humus fabric in a managed forest. Use of morphometric image analysis of thin sections

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In a managed fir forest (calcareous substratum) of the Southern French Alps, soil fauna communities were strongly affected by small circular clearcuttings (Caner *et al.*, 2001). Significant changes in the distribution of earthworm ecological groups were found between forest and clearing plots in spite of a similar total density and biomass. Epigeic worms were mostly found in clearings whereas forest plots were dominated by endogeic worms. Morphological characterization of humus forms revealed a mull type in both cases. However, differences in humus fabric of the A horizon were observed between forest and clearing plots : an angular blocky fabric under forest and a crumb structure under clearing. By means of humus thin sections, we tried to understand near-surface soil structuration processes. We used a quantitative image analysis method created by Ringrose-Voase & Bullock (1984) and recently developed by Vandenbygaart *et al.* (2000). For a similar total porosity, a change in pore types was found between forest and clearing plots. A horizons in Forests plots were mostly characterized by fissures (poric angular blocky fabric) whereas those under clearing had numerous mammillated vughs (poric crumb fabric). The results demonstrate that near-surface soil under forest is mainly structured by physical processes (wet-dry cycles) while clearings depend on biological processes creating soil biogenic structures. Sylvicultural practices have a strong impact on forest humus, clearcutting changes soil biodiversity leading to an important modification of soil structuration processes.

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Comparison of the seed bank of ant mounds and pasture soil

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Nest-building ants impact the vegetation of grasslands by changes in physico-chemical soil conditions, biting leaves and roots, covering of plants with soil, and alterations of the seed bank. This leads to small-scale changes in plant species richness and community composition that may even persist after abandonment of the mounds. The mound vegetation generally is a sub-sample of the species occurring in the interspace, but facilitation of certain species at the mounds (e.g. poor competitors to grasses) may increase overall plant diversity. However, the effects of ecosystem engineering of non-seed dispersing ants on the soil seed bank is poorly understood.

We have studied the impact of nest-building ants on the vegetation of a low-intensity grazed pasture (Central Hesse, Germany). The current vegetation of *Lasius flavus* (F.) mounds was compared to that growing between the mounds. In addition, soil conditions (water content, pH, N_{min}) and composition of the seed bank on and off mounds were analysed from soil samples taken at a 546m² subplot of the site. Seedlings growing from the soil samples for a period of 23 weeks were counted and determined.

Surveys of the current vegetation showed two distinct types of ant mounds, either being dominated by herbs (H mounds) or by grasses (G mounds). Water content and pH was significantly higher in the soil of the pasture (P) than in that of H/G. Nitrogen content of H/G soils was not different from the P soil, but it was lower in the H than in the G soil. Of the 65 vascular plant species growing at the study site 9 were exclusively found on H/G, while 19 only occurred in P. Consequently, mean species richness was higher in P (18.5) than on H/G (12). Therophytes had a high affinity to H/G, while hemikryptophytes of nutrient rich soils preferred P. Vegetation of H was dominated by *Thymus pulegioides* and that of G by *Festuca ovina*. A total of 43 species was found in the soil seed bank. Species richness of seedlings was higher in P compared to G. In contrast the number of seedlings was higher in G compared to P. Species richness and number of seedlings of H was intermediate between P and G. The composition of the seed banks mirrored that of the current vegetation. Although almost twice as much seedlings grew in the soil of H and G than in the P soil, current vegetation density was lower on H and G than in P.

Differences in species richness between ant mounds and pasture soil were much less pronounced in the seed bank compared to the current vegetation. We thus conclude that soil engineering is much more important for the effects of ants on the pasture vegetation than alterations of the soil seed bank.

Modifications of the microbial community structure during transit of organic matter through the earthworm gut

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The vermicomposting process consists basically of two different sub-processes. The first involves the earthworm gut-associated processes (GAPs), which include all the modifications that the organic matter undergo during transit through the intestinal tract, including the transformation of nutrients, modifications and increases in microbial diversity and activity, modifications of microfaunal populations, homogenization, and the processes of digestion, assimilation, and excretion wastes. Once the earthworm GAPs end, the resultant casts are exposed to cast-associated processes (CAP); here, the effects of the earthworms may be only indirect and include aeration of the substrate because of the burrowing activities. Moreover, earthworm casts are subject to an aging process and to the action of microorganisms and microinvertebrates present in the substrate; it is important to note that, during action of the vermicomposting systems, the casts are mixed with materials that were not eaten by the earthworms.

In this study, we used phospholipids fatty acid (PLFA) analysis to determine and quantify the modifications of the microbial community structure during transit through the earthworm gut. We also studied the earthworm specific effect, by comparing the modifications of the microbial community structure of the same organic material through the gut transit in six epigeic species. We analysed the PLFA in two parent materials (cow and pig manure) and in fresh casts of six earthworm species: *Eisenia andrei*, *Eisenia fetida*, *Eudrilus eugeniae*, *Lumbricus rubellus*, *Dendrobaena rubida* y *Allolobophora caliginosa*. We set up three earthworm cultures for each species and used composite samples of each culture.

Our results provide new insight into how gut associated processes of earthworms modify the microbial community structure of the organic matter.

Earthworm diversity and structural stability on agricultural soils of a loamy plateau (France, Normandy)

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The loamy soils of the Paris Basin are widely used for intensive agriculture characterised by a frequent and strong soil tillage. Current agronomic studies tend to identify systems (no-tillage systems, crop/pasture rotations, biological culture...) that may constitute alternative to productivist agriculture. In a previous work, we described earthworm communities in a system of crop/temporary pasture rotation. Based on these results, we investigated the changes in soil structural stability during implantation of temporary pastures and their relationships with earthworm diversity. Study plots were located in the agricultural high school of Yvetot (Haute-Normandie). This site provides a large range of plots on eolian loess, that are managed as temporary to permanent grasslands, or crops. Five grasslands were chosen for this study, in order to represent a chronosequence through a synchronic approach.

Soil structural stability was estimated from superficial soil samples (0–5 cm) using the Le Bissonnais method (Le Bissonnais, 1996). This method allow to distinguish different factors that may alter soil structure: (i) bursting, (ii) differential swelling followed by bursting and (iii) mechanical desaggregation. Each of these mechanisms relies to particular pluviometric conditions: intensive rainfall on a dry soil, intensive rainfall on a saturated soil, fine rainfall on a humid soil, respectively. Results were expressed in mean weight diameter (MWD).

Earthworm species richness is strongly depleted during pasture establishment, but regain a level similar to permanent grasslands after about 3-4 years. The structural stability of the superficial soil layer presents values that are little subjected to crusting. Tests of mechanical desaggregation by swelling and bursting show that the MWD of the soil is not significantly different in 2-3 year olds and permanent pastures. However, tests of desaggregation by bursting indicate a constant increase of MWD with grassland ageing.

In conclusion, an empirical relationship appears between soil structural stability and earthworm specific richness. This relationship is more or less linear, depending on the type of destructuration considered and the hydric regime simulated.

Using actinomycete and bacterial specific PCR primers to characterize the bacterial communities of wormcasts

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Tropical geophageous earthworms stimulate soil bacterial activity in soil that they ingest; it is uncertain if they affect the whole bacterial population or only subgroups. We sampled *Martiodrillus heterostichon*, *Polypheretima elongata* and bulk soil from a Bamboo grove near Cali, Colombia. Pots of 1 500 g of an adjacent tobacco field soil were brought to field capacity and two worms of each species placed in each pot. *Martiodrillus* gut contents and wormcasts from the soil surface and within tunnels were sampled after three months. The soil was maintained at field capacity for a further five months during which the worms continued to produce casts. Worm cast Amplified ribosomal DNA restriction analysis ARDRA (using *Taq* I) with actinomycete specific primers gave two strong bands at approximately 750 and 370 bp. ARDRA patterns from the three bamboo and four field soils had several additional bands notably at 140 and 126 bp. Thirty clones generated with actinomycete specific primers from a cultivated soil (6), bamboo soil (4), *Martiodrillus* gut contents (10) and a *Polypheretima* cast (10) were sequenced. Sequence comparison with the BLAST database and simulated *Taq* I digestions using DNAMAN found that many clones were verrucomicrobial. Simulated digestions of verrucomicrobial clones gave bands that matched the dominant bands in the bamboo and tobacco soils. Simulated *Taq* I digestion of actinomycete clones gave bands similar to those in wormcasts. Most actinomycetes gave non-streptomycete BLAST matches. Seven actinomycete clones found in wormcasts were > 97 % similar and were from the Nocardiodes. Four actinomycete clones found in both worm casts and bulk soil match environmental clones which have no closely related cultivated strains. Cloning and sequencing results from bacterial primers suggest that the worm casts were enriched with proteobacteria. There is clear evidence that digestion of soil by Tropical geophageous earthworms changes the soil bacterial community structure.

The microbiological characteristics on the *Lasius niger* ant mound nest soil on the post mining sites and meadows

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Microbiological soil properties and basic chemical and physical parameters of *Lasius niger* ant mound and surrounding soil has been studied in two contrasting habitats: post mining sites (tertiary clay spoil heap) and in meadows in surrounding landscape in Sokolov coal mining area (Czech Republic). Soil respiration in situ of *Lasius niger* mound was significantly higher comparing control soil. Total count of bacteria was two times higher than in ant nest mound. Microbial biomass was not differ significantly between nest and surrounding soil. Litter bag test show lower cellulose decomposition rate in ant nest mound. Total carbon was significantly lower in ant nest. Total and available form of phosphorus and potassium was significantly higher in ant mounds. pH value was significantly higher in ant nest soil. Bulk density and soil moisture was significantly lower in ant mound. Total carbon in ant nest was reduced comparing control soil, probably due to soil mixture with lower soil horizon. Available form of phosphorus was higher in ant nest. Ant nest mound soil moisture was significantly reduced comparing control soil. Moisture affect significantly respiration of both nest and surrounding soil.

From the biology of ecosystem engineers to the community structure of soil microorganisms. The case of fungus-growing termites in an African savanna of Côte d'Ivoire

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Amongst soil macrofauna, fungus-growing termites (Isoptera, Macrotermitinae) constitute a major component of savanna and forest ecosystems in tropical and subtropical Southeast Asia and Africa. To understand the impact of fungus-growing termites on ecosystems, termite species are usually considered among the same functional- (or feeding-) group, according to similarities in their trophic pathways and in their action on soils. The aim of this study is to discuss about the validity of this functional group concept applying to fungus-growing termites for characterising their impact on the diversity of soil microorganisms. The following hypotheses were tested : (i) subterranean fungus-growing termites might significantly alter the microbial community structure within their nests (fungus-comb chambers) and (ii) these effects are different for different termite species.

The investigations were carried out with material collected from the fungus-comb chamber walls of two wide-spread species differing in the mode of nest construction: *Ancistrotermes cavithorax* build temporary nests whereas *Odontotermes* nr. *pauperans* inhabit their mounds for several years, occupying the same area for a comparatively long period of time and modifying drastically the soil properties. Automated rRNA intergenic spacer analysis (ARISA) was used to characterise bacterial (B-ARISA) and fungal (F-ARISA) communities. Our results illustrate that *Ancistrotermes cavithorax* has lesser impact on the structure of bacterial and fungal communities than *Odontotermes* nr. *pauperans*. One conclusion of this study is that "life-time" of biogenic structures is an important parameter when we want to define the "functionality" of fungus-growing termites.

Comparative analysis of nutritional and microbial parameters of earthworm cast and termite mound soil

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A comparative analysis of nutritional and microbial parameters was conducted on two types of biogenetic structures of earthworm cast (87mm in height, 7 towers/m²) formed by litter eating *Pheretima* sp., and mound(640mm in height, 20 mounds/ha) built by fungus growing termite, *Macrotermes gilvus*, and compared to the ambient soil in the monsoon forest in Hoh Chi Minh City of Viet Nam. Casts were different from termite mounds in their C and N contents which were approximately six times as high. Bacterial counts and soil enzymatic activities of beta-glucosidase and urease in casts were greatly higher than those in the ambient soils, although microbial population, and available N and P in termite mound soils were significantly lower than those measured in their surrounding soils. On the whole, these results suggest that plant nutrition is stored in the earthworm cast, but mound soil of fungus growing termite is infertile.

Termites as ecosystem engineers: An example of the role of the fungus growing termites in a tropical savannas functioning, with some evolutionary implications

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West African Savannas are important ecosystems where termites represent a conspicuous figure and, with the earthworms and ants, the dominant macroarthropods. Because of their effect on hydrology and nutrient cycling in tropical savannas, termites are called ecosystem engineers, as they can modulate the availability of these resources to other species, by causing physical state changes in abiotic materials. In a guinean preforest savanna (Lamto, Côte d'Ivoire), the termite mounds of *Odontotermes* sp represent a major source of heterogeneity in the landscape, occupying up to 8% of the area in some biotopes and representing about 300 m³ of soil per ha. These mounds are sites of intense and permanent activity of soil fauna and are characterized by a higher vegetation density as compared to the surrounding savannah. The work undertaken try to understand the effect of termite building activities on soil physical modification and soil water and nutrient status as well as vegetation structure and diversity, taken as an example of ecosystem engineering. A spatio-temporal variation of soil water potential was surveyed in the field by the means of soil moisture probes, and undisturbed soil samples were collected for the study of soil characteristics in the laboratory. CO₂ evolution from the soil surface was measured using a close chamber system, in the field, and mass-specific respiration rate of the different components of termite fungus chambers was measured under laboratory conditions. The leaf shedding patterns of deciduous shrubs were followed at the beginning of the dry season. Soil texture and structure were found to be strongly modified on the termite mound as compared to the surrounding control soil. Clay content was higher on the mound than in the control area, and we found a noticeable percentage of interstratified clay minerals (illite/smectite) on termite mound. The temporal variations in the soil water potential was strongly correlated to the rainfall pattern, and the maximum soil water content available for plants was higher on the mound than in control area. The leaf shedding pattern of shrubs located on mounds was less pronounced than that of individuals located on control soil. At the landscape-scale, the CO₂ emission due to the termites represented 4.9% of the total aboveground net primary production in this ecosystem and 11.3% of the carbon not mineralised by annual fires. Our study demonstrated the concept of ecosystem engineers in the fungus growing termites, and brought an open question about the extended phenotype concept: could the effects of termitaria on plants have a positive return upon the termite populations, and then could it be a selected feature driven by evolution? We proposed some lines of answers, based on laboratory experiments and field observations.

Intracellular endosymbiont bacteria associated with their soil-dwelling *Xiphinema americanum*-group Cobb, 1913 (Nematoda: Longidoridae) nematode hosts

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The soil-dwelling nematode group *Xiphinema americanum* has a global distribution. A number of the putative species belonging to this nematode group cause substantial economic damage to a wide range of crops by transmitting one of four different nepoviruses to plants.

Recent studies on these nematodes have shown that they contain intracellular endosymbiotic bacteria, belonging to the *Veruccomicrobia*, in their reproductive systems. It has been suggested that these bacteria are directly implicated with parthenogenetic reproduction predominant in *X. americanum*-group nematode species thus analogous to parthenogenesis inducing *Wolbachia* strains in arthropods. In addition to parthenogenesis, *Wolbachia* are known to alter arthropod reproductive strategies by inducing male killing, feminization and cytoplasmic incompatibility and may affect the evolution of their hosts. Whilst *Wolbachia* are widespread in arthropods and filarial nematodes, they are absent from the few non-filarial nematode taxa investigated.

This project examined inheritance patterns from *Veruccomicrobia* and their host nematodes using molecular DNA markers to identify the pattern of events that have led to their current distribution and diversity, and how the bacteria are transferred within the nematode populations, i.e. transmitted vertically (maternally) or horizontally (between unrelated individuals or hosts).

Thirty-four different *X. americanum* populations from disparate geographic areas throughout the world were studied using markers for bacterial 16S ribosomal DNA (rDNA) and nematode 18S rDNA genes. A subset of the nematode populations was also studied using a mitochondrial DNA (mtDNA) marker, COI. Both nematode and bacterial DNA were extracted simultaneously from individual nematodes.

Using the recognised criteria of 3 % sequence dissimilarity, ten possible different strains/species of intracellular bacteria were recorded. Previous studies have reported only three such strains/species of *Veruccomicrobia*.

Comparison of phylogenetic trees derived from a) 16S and 18S rDNA sequence data from all 34 *X. americanum* populations studied and b) COI and 16S sequence data from a subset of host nematode populations showed evidence of vertical inheritance patterns, i.e. the intracellular bacteria are likely to be maternally inherited as they are related to the mitochondria from the same host. However, given the lack of complete congruence amongst the phylogenetic trees, some limited horizontal transfer cannot be excluded.

Soil aggregation, invertebrates and litter quality in laboratory experimentation: interactions between earthworms and woodlice

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The invertebrate community play an important role in terrestrial ecosystems processes by recycling soil organic matter and by participating in nutrient cycling. Soil fauna also structure their dwelling by digging galleries and by mixing soil materials, so it plays an important role in humification process and in the formation of organo-mineral aggregates. Soils animals were classified in different functional groups (Lavelle, 1997): *microorganisms*, *micropredators*, *litter transformers* and *ecosystem engineers*. This classification is based on the ability of the organisms to digest soil organic matter and to modify soil structure. Interactions between *ecosystem engineers* and *litter transformers* have been observed (e.g., Loranger *et al.*, 1998). However, these relationships are not thoroughly understood. In this study, effects of *ecosystem engineers* (endogeic earthworms *Aporrectodea caliginosa*) and *litter transformers* (woodlice *Porcellio scaber*) on soil aggregation were investigated in laboratory microcosms with different litter quality.

Soil, leaves and soil animals were collected in Fontainebleau forest. The soil is a sandy-loam. Leaf litter was taken from the OL layer of the forest; two species were chosen: *Quercus robur* (oak) and *Fagus sylvatica* (beech). *A. caliginosa* and *P. scaber* were collected and sorted by hand from a soil block. Microcosms were filled with 1,8 kg dry weight of soil. Leaves (6 g) and animals (3 woodlice or/and 3 earthworms) were placed on the soil surface. The experiment was set up in a factorial design with the factor “earthworm” (with and without *A. caliginosa*), “woodlouse” (with and without *P. scaber*) and “leaf litter” (with and without oak or/and beech), with three replicates of each treatment. After 4 months of incubation, soil was sampled using cylinders (6 cm diameter, 5 cm high). Aggregate size distribution was measured using a dry-sieving method. Soil aggregates were separated into 22 fractions gathered in 4 size classes: ultrafine (< 0.4 mm), very fine (0.4 - 0.63 mm), fine (0.63 - 2 mm) and medium (> 2 mm).

At the end of the experiment, the proportion of macro-aggregates (> 2 mm) differed significantly among the treatments ($P < 0.0001$). Endogeic earthworms play an important in macro-aggregates formation contrary to woodlice. Earthworms produced little proportion of macro-aggregates under oak. Earthworms fed preferentially on beech. However, in presence of woodlice and oak, they produce more macro-aggregates; they probably fed on woodlice faeces and oak leaves fragmented by these litter transformers. Identically, woodlice fed preferentially on oak and probably fed on earthworm casts in presence of beech. Litter play an important role on aggregation via its action on soil fauna. A strong mutualism relationship was suggested between the two functional groups when one of them fed on litter of poor quality.

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Changes in soil aggregate distribution after mass emergence of the geophagous millipede *Parafontaria laminata*

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Exactly 8 years periodical swarming of the adult millipede (*Parafontaria laminata*) have been known at Mt. Yatsugatake, central Japan. We observed the soil structure changes by the millipede fecal pellet due to feeding soil and litter after mass emergence of the adult millipede on September 2000.

Field investigation was performed for three years (2001-2003) to analyse soil aggregate distribution, total carbon and nitrogen at high (311 m⁻²) and low (17 m⁻²) density sites. The ratio of macroaggregates (>2mm) was higher at high density site than at low density site and it increased in 2002 and decreased in 2003, whereas the aggregate distribution at low density site showed no marked change for three years.

In laboratory experiment, the adult millipede was incubated at 15°C in the plastic container with soil and larch litter. Total carbon and nitrogen contents and ¹³C, ¹⁵N stable isotope ratio were measured in fecal pellet of the millipede, litter and soil. Carbon and nitrogen concentration of fecal pellet (C: 33.74%, N: 1.75%) was high compared to soil (C: 19.99%, N: 1.22%) and was lower concentration than litter (C: 50.37%, N: 1.95%). The value of ¹³C, ¹⁵N stable isotope ratio of fecal pellet (delta ¹³C: -24 par mil, delta ¹⁵N: 2.7 par mil) was intermediate between litter (delta ¹³C: -27 par mil, delta ¹⁵N: 0.03 par mil) and soil (delta ¹³C: -20 par mil, delta ¹⁵N: -6.2 par mil). Thus the adult millipede fecal pellets incorporated a large amount of litter organic matter into mineral soil.

The millipede adults lived less than one year, and all the adults died by the August 2001. Therefore, the observed changes in the soil aggregates might be linked to community change due to the millipede mass emergence in 2000. Persistence of the soil aggregates after the mass emergence of the adult millipede might be due to viscous material of microorganisms or mucigels of plant roots. These results suggested that the geophagous millipede feeding activity closely associated with the increase of the soil macroaggregates and organic matter in short term.

Earthworms enhance fungal activity in a bacterial-dominated ecosystem

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Decaying organic materials support large amounts of microorganisms and specialized faunal groups, and their rates of turnover and release of nutrients depend on the activity of these organisms. Main factors affecting decomposers activity are availability and composition of the organic matter and the trophic relationships between organisms.

In organic wastes such as animal manures, high moisture contents and presence of easily decomposable compounds rich in C and N favours bacterial-based food webs. Nevertheless, the trophic structure of the decomposer food web can be strongly affected by different factors such as the physical structure of the substrate and the availability of resources. Burrowing and casting activities of large saprophagous organisms like earthworms affects dramatically both structure of decaying organic matter and resource availability allowing the development of a wider range of microorganisms and microbivorous fauna. Specifically, earthworm disturbance may promote fungal growth and the development of the associated fungivorous fauna.

In order to measure how earthworms affect the microflora and the associated faunal populations during decomposition of organic matter, continuous feeding vermireactors with (n=6) and without earthworms (n=6) were set up. Vermireactors were fed with pig slurry in dated layers, to control rates and amount of added organic matter. After one year, these dated layers were analysed for microbial biomass and activity, nematode trophic structure and collembolan populations.

Earthworm activity increased bacterial and fungal biomass-C and respiration rates. Nematode trophic structure was also altered. Fungal feeders were found in higher numbers in presence of earthworms while bacterial feeders sometimes decreased. Earthworms also increased presence of collembolans strongly, a main group of fungal feeders. Fungal biomass and its associated fungivorous fauna was quickly promoted by earthworm presence but they tend to decrease through time. Earthworm activity promoted the development of a short-time fungal-based food web improving decomposition rates through increasing trophic diversity.

Abundance of biogenic structures of earthworms and termites in a mango orchard

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Termites and earthworms are physical ecosystem engineers and play a central role in important ecosystem function such as soil structure dynamics and organic matter cycling. Their activity results into the formation of the so-called biogenic structures. However, at the ecosystem level, the population impact of a given Ecosystem Engineer is partly modulated by its pattern of distribution. Because their populations often display non-random spatial distribution, accounting for that spatial pattern greatly improve our capacity to understand their functional impact. There are however few data available on the spatial pattern of biogenic structures. This study examined the spatial distribution of various biogenic structures in a mango orchard at Thiès (Senegal). Three sampling campaigns, at the beginning and end of the dry season and during the wet season, were done. At each date, the abundance of earthworm casts and termite sheeting and filling structures were recorded in two 100 m transects. Biogenic structures were collected every 5 m along the transect in 1 m² sampling units. All structures were dried at 105°C and weighed. In addition, each sampling location was described by several variables (e.g. presence/absence of litter, number of plant species, importance of herbaceous cover...). The presence of spatial autocorrelation in the transect data was assessed using Geary's index. A Multiple Correspondence Analysis allowed to process qualitative and quantitative data after transforming the latter into classes. This survey showed that surface biogenic structures may represent a large amount of modified soil (up to 523g per m²) which vary depending upon the seasons and the species. Whilst the quantity of casts was independent on the season (184 g/m²), termite sheetings fluctuated with the seasons. For example *O. nilensis*' sheetings were abundant during the dry season (333g/m²) but absent in the wet season. In addition, we show that the spatial organization of surface biogenic structures fluctuates with seasons. It displays patches ranging from 5 to 15 meters. There is a link between the distribution of earthworm casts and the vegetation. During the dry season, earthworm casts were found under mango trees, presumably because of better habitat conditions. In addition, spatial distribution was also linked to the biology of constructing species. *A. guineensis* are well known to build filling structures in the pieces of wood located on the soil surface. However, we observed that the *A. guineensis*' sheetings were mainly located under the mango trees during the dry season where the stems and the brushwoods were abundant. To conclude, it appears that the spatio-temporal distribution of the biogenic structures under study depended upon two main factors: season and vegetation. However, depending upon the biology of the engineer, these two factors influenced the spatial distribution of structures in different ways.

The effect of excretes of the earthworm *Aporrectodea caliginosa* on soil respiration

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Earthworms are known to significantly modify microbial biomass (Tiunov, Scheu, 1999) and composition of microbial community (Tiunov et al., 1997) in drilosphere. The only earthworm species extensively studied was *Lumbricus terrestris*. To date little is known about mechanisms by which earthworms control the microbial community in the burrow walls. We tested the metabolic hypothesis according to which earthworm excretes (surfaces mucus and excrements) may regulate microbial activity. To obtain the excretes, adult endogeic earthworms *Aporrectodea caliginosa* were placed in tempered (45^o C, 5 hours) and moisten sand for 1 day. Water soluble compounds were extracted with distilled water. The earthworm excretes contained 250 µg organic C, less than 0.6 µg of glucose and 4.7 x 10⁻⁴ µg NH₄⁺ per worm. The excretes contained 100 - 200 CFU of fungi and 2000 – 5000 of bacteria per worm. Five g of air-dried soddy-podzolic soil was moistened to 25% with either native or autoclave sterilized excretes to obtain final concentrations 16, 8 and 1.6 µg C/g soil. The flasks were kept at 15^o C for 14 days. Respiration activity was measured by the use of gas chromatography.

The excretes were shown to suppress soil respiration up to 25-30% as compared to the soil treated with water. Both sterile and non-sterile excretes, those diluted and non-diluted suppressed the microbial activity. The effect eliminated by the day 3 of incubation. It was calculated the mass of drilosphere soil with the burrow 10 cm in length (equal to the length of 1 worm) to be ca. 1 g. Therefore, theoretically the drilosphere soil may receive from 1 worm 250 µg organic C per day. It is comparable to the concentration of soluble organic matter found in the soddy-podzolic soil. Thus, on a local level the earthworms can add to the drilosphere soil organic compounds, which amount should be enough to stimulate microbial activity. The excretes, however, did not stimulate, but suppressed the microbial respiration. The fact that the sterilized and non-sterile excretes showed similar inhibitory activity indicated that the earthworm excretes contain selective antimicrobial compounds. These compounds seem to act at very low concentrations.

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Ant-tree aphid mutualism: effects on community structure of soil microorganisms

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Studies on the impact of soil macrofauna on soil microorganisms commonly investigate the macrofauna effects on physical and chemical soil properties, i.e. through the building of biogenic structures. In contrast, the modification of soil microbial communities by trophic pathways of soil macrofauna has received little attention. An example is the mutualism between the invasive ant species *Lasius neglectus* (Hymenoptera, Formicidae) and the tree aphid *Lachnus roboris* (Aphidina, Lachnidae). The number of aphids on trees tended by this polygynous invasive ant is very high compared to the activities of native ants. Therefore, the production of honeydew and the amount of honeydew sticking on leaf litter or being washed from infested trees are greater than on non-infested trees. Quantitative measures indicate that ants might extract a total of 1.13 kg honeydew per year and tree from the evergreen oak (*Quercus ilex*). The aim of our study is to test whether the carbon fertilisation beneath tree crowns leads to a change of the community structure of soil microflora and, consequently, on the nutrient cycle. The investigations were carried out in Seva, NE Spain with soil collected from beneath the crowns of infested and non-infested *Quercus ilex* trees. Soil physical (water content, texture, pH and CE), chemical (C, N, S and P content) and biological (microbial biomass) properties were assessed for each type of soil. In addition, Automated rRNA Intergenic Spacer Analysis (ARISA) was used to characterise soil bacterial (B-ARISA) and fungal (F-ARISA) communities.

Total amount of carbon and nitrogen and microbial biomass (Cmic) in the soil were significantly higher beneath infested trees. Soil physical properties and phosphorous content did not differ between the two types of trees. ARISA profiles indicated a significant shift of both bacterial and fungal communities structure beneath infested trees due to the carbon fertilisation. Data also showed a decreasing variability of the microbial genetic structure in soil beneath infested trees, suggesting a great structuring stress on microbial community populations.

Our results illustrate that ants, through their mutualism with tree aphids, can locally influence the soil bacterial and fungal communities. Therefore, pest damage on the tree caused by this invasive ant species has two consequences: a direct cost for trees but also an indirect impact on soil nutrient cycles. More generally, we conclude that a thorough understanding of the relationships between soil macrofauna and soil microorganisms needs also to consider the consequences of the interactions between macroorganisms themselves.

3D morphological characteristics of natural burrow network in relation to different earthworm species. Influence on water transfers

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Earthworms have a large impact on soil properties (physical, chemical and biological properties), so that they are considered as "ecosystem engineers". In particular, they modify the soil porosity by creating burrows. The burrows network (macropore space, >1mm) can act as preferential flow path. This water movement depends on the geo-morphological characteristics of each burrow. In fact, a number of studies have documented burrow characteristics. But, those studies, which have generally been carried out in artificially soil, often link the burrow characteristics to one earthworm species without taking into account the strong interactions which exist between earthworms species. Moreover, in relation to the spatial organization of the networks of burrows, a picture in two dimensions is not sufficient. It is advisable to use tools that give the representation of this macroporosity in three dimensions.

The aim of our study was 1) to characterize in three dimensions the earthworm burrows observed in natural conditions, under different agricultural practices, 2) to link these characteristics to the earthworm species sampled *in situ*. Afterwards, we assessed the influence of those burrow characteristics on the water infiltration in order to identify the most efficient geo-morphological characteristics on the water movement.

Investigations were conducted in western Brittany (France) under three different agricultural managements (a continuous maize field, a rye-grass/maize rotation, an old pasture). Earthworm communities were sampled in each field. At the same place, soil blocks (25*25*25 cm) were sampled and scanned by X-ray computed tomography; the burrow systems were characterized by large number of morphological characteristics. Afterwards, the saturated water conductivity K_{sat} of each block was measured.

The burrow systems present different geometric morphologies depending on the agricultural managements and the earthworm species present. There is no correlation between the number of burrows or the geometrical properties, except the rate of branching, and the infiltration rate. The infiltration rate seems to be essentially linked to the connections of burrows with the soil surface. The burrows of *L. terrestris* seem to be more efficient for water infiltration compared to those created by *A. giardi*.

Saprotrophic microfungi and oribatid mites of *Dendrobaena mrazeki* casts in a thermophilous oak forest

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Dendrobaena mrazeki is an endemic earthworm distributed across a small part of Central Europe. It shows preferences for dry habitats, xerophilous oak forests or pine forests on sandy soils, hostile for other earthworm species. There are suggestions that in such ecosystems, *D. mrazeki* may reach remarkable density and produce large amounts of characteristic casts composed of well recognisable pellets.

Four experimental plots (100 x 100 m) were established in thermophilous oak (*Quercion pubescenti-petraeae*) forests in the Pálava Biosphere Reserve (southern Moravia, Czech Republic). Three subplots (1 x 1 m) were randomly demarcated at each plot in spring 2003, cleaned of earthworm casts and used for the measurement of cast production by *Dendrobaena mrazeki* populations. To assess the earthworm effect on saprotrophic fungi and oribatid mites, samples of *D. mrazeki* casts, overwintered *Quercus* litter and mineral soil were collected in July 2003. The CFU numbers and composition of fungal community were analysed using the washing and plating method, and epifluorescent microscopic method was used for the estimation of mycelial length. Oribatid mites were extracted using the modified high-gradient extractor and identified at the species level.

The results showed that the population of *D. mrazeki* produced monthly up to 450 g of surface casts per square meter. The diversity and CFU numbers of fungi in earthworm casts tended to be higher than in surrounding soil but lower than in litter. Length of fungal mycelium was the highest in *D. mrazeki* casts at two plots, but lower than that in soil at other two plots. The lowest values of mycelial length were measured in litter. The community of oribatid mites was much richer in litter and soil than in casts. In both litter and soil, the most frequent mites were euryoecious species *Tectocepheus velatus*, *Micropoppia minus* and *Oppiella nova*. In contrast, cast community was dominated by xerothermic mites *Licnodamaeus pulcherrimus* and *Zetrochestes micronychynus*. The study suggests that *Dendrobaena mrazeki* could affect significantly the spatial distribution of microbial and faunal communities in dry soil of thermophilous oak forests.

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Collembola control the growth of earthworms by changing the availability of carbon

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Earthworms are able to affect the abundance of soil mesofaunal groups in many ways. These effects can be positive, e.g. by improving habitats or enhancing availability of food, or negative, e.g. by competing for food or by causing mechanical perturbations during burrowing activities. In contrast, the opposite view of this relationship, i.e. how mesofaunal groups affect earthworms, has mostly been ignored. Positive as well as negative effects of soil mesofauna on earthworms are imaginable: Some mesofaunal groups could act as a prey for earthworms (positive) or could compete for food resources with earthworms (negative). Beside these direct effects, indirect effects are possible: Mesofauna could change microbial biomass or microfaunal communities by (selective) grazing, or alter carbon and nutrient fluxes in the soil. The application of organic carbon resources (glucose) and nutrients in laboratory and field experiments showed, that biomass and abundance of some earthworm species are dependent on the availability of labile organic carbon. Thus, effects of Collembola and other mesofaunal groups on carbon availability could alter the growth of earthworms.

We performed an experiment to answer the questions, if two collembolan species, *Protaphorura fimata* and *Folsomia candida*, are able to affect the growth of the endogaecic earthworm species *Octolasion tyrtaeum* and *Allolobophora chlorotica* generally, and if the Collembola are able to affect the growth of the earthworms via changing the availability of organic carbon. We set up a laboratory experiment with microcosms containing no collembolans, each collembolan species alone or both species in combination. One individual of *O. tyrtaeum* or *A. chlorotica* was added to each collembolan treatment. Half of the microcosms received glucose addition, the other half did not.

As expected, biomass of both earthworm species increased in microcosms with application of carbon much stronger than in microcosms without additional carbon. *O. tyrtaeum* showed no clear responses to the presence of Collembola in microcosms with or without application of glucose, whereas the growth of *A. chlorotica* was affected significantly: In microcosms without glucose application the growth of *A. chlorotica* was only slightly negatively affected by the presence of Collembola, independent of collembolan species or densities. In microcosms with glucose addition the presence of one collembolan species alone inhibited the growth of *A. chlorotica*, whereas in microcosms with no Collembola or both species biomass of *A. chlorotica* was increased. Presumably, changes in microbial communities or competition for carbon between earthworms and higher numbers of microorganisms ("catalysed" by grazing of collembola) were responsible for the obtained results.

Fungal and bacterial community composition in soil feeding termite nests (*Cubitermes* sp.) and tropical soils from Gabon

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Molecular microbial ecology has revealed remarkable biodiversity - prokaryotic and eukaryotic - in numerous soil environments. However, few culture-independent surveys of the termitosphere exists although termites dominate tropical rainforests. Here we focused on soil-feeders of the genus *Cubitermes*, building nests with their soil-born faeces, enriched with clay-organic complexes, thus contributing to the improvement of soil fertility.

Termitaries and soil samples were collected in the Lopé rainforest, Gabon, and processed for generation of fungal Internal Transcribed Spacer (ITS) and bacterial 16S rRNA gene libraries. Most of the recovered sequences represented Fungi and Bacteria with the previously uncharacterised at species level as revealed by BLAST searches against public sequence databases and whose proportions reached 74% for Fungi and 89% for Bacteria.

Phylogenetic analyses were performed in order to affiliate the recovered phylotypes with identified Fungi and Bacteria based on 5.8S rDNA and 16S rRNA gene, respectively. However, 29% of the fungal phylotypes and 26% of the bacterial phylotypes remained unclassified, revealing the wide unknown diversity of micro-organisms present in the studied samples.

Furthermore, the microbial communities of soil-feeding termitaries and soils shared only 6.3% and 4.8% of sequences for Fungi and Bacteria, respectively. This discrepancy of composition between soils and nests may result from the building behaviour of termites, since the organic matter in the nest is chemically modified and some vacant ecological micro-niches are available for more specialised micro-organisms.

How many observations are needed for regional estimation of soil macrofauna biodiversity? An *a posteriori* analysis of different sampling intensities using bootstrap resampling

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In the tropics, soil macrofauna is generally sampled following the recommendations by the Tropical Soil Biology and Fertility (TSBF) programme: a minimum of 5 and preferably 10 soil monoliths (25 cm × 25 cm by 30 cm deep) are hand-sorted to collect fauna [1]. This procedure yields accurate pictures of biomass and density patterns amongst different sites and consistent within-site results. However, we question its accuracy at picking up species richness and diversity. This study explored the performances of various sampling regimes using an extensive data set collected in the Benfica region, southeastern Amazonia, Brazil. The study site consisted into a somewhat complex landscape mainly featuring primary forest, various fallow types, different crops (e.g. rice) and pastures. A set of 23 plots was surveyed using various sampling intensities ranging from 5 to 25 samples and following the TSBF procedure. A total of 270 sampling units were examined. On the basis of this data set, we assessed the performance of various sampling intensities at two distinct scales: a) the local scale that corresponds to the landscape units and b) the regional scale where we considered all landscape units simultaneously. We used the bootstrap resampling method to estimate the species richness and various associated attributes (e.g. estimator bias, confidence limits...) and to examine how the accuracy of these estimates was changing with increasing (re-) sampling intensity. By doing so, we simulated the potential expected improvements in the sampling performance associated with an increased sampling effort. At the local scale (landscape units) when 5 sampling units were used, the bias on the richness estimate ranged from 35 to 69% i.e. the proportion of species that weren't accounted for was roughly from 1/3 to 2/3 depending on the locations. This proportion decreased to 21 - 49% when 10 samples were considered. At the regional level we assessed the value of 3 different sampling intensities: 2, 5 or 10 samples per landscape units. All these sampling intensities led to poor quality estimates since the species richness was always underestimated by 61 to 26 %. We conclude that sampling soil macrofauna using the TSBF method leads to particularly weak estimates of the species richness. There are obvious reasons for such a poor performance like the very high proportion of species represented by only a single specimen (i.e. singletons) and the low number of species common to comparable landscapes units (shared species). Therefore caution is needed when sampling devices are designed to investigate soil fauna biodiversity and alternative methods should be considered.

Reference

[1] Anderson & Ingram 1989 Tropical Soil Biology and Fertility: a Handbook of Methods CABI Publishing

Syntrophic mutualism in the earthworm gut: new evidences from fatty acid biomarkers

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Despite the relevance of earthworms in large scale soil processes such as soil fertility, soil formation and stability, and even with the large effort on earthworm biology and ecology, the digestive function of this group of soil fauna remains virtually unknown. Specifically, little is known about the role of the microorganisms inhabiting the earthworm gut, since only culturable microorganisms (accounting for only 1 to 10% of the total microorganisms in the gut) have been identified so far.

In this paper we studied the diversity of the microbial community in the gut of *Lumbricus terrestris* L. and bulk soil analyzing whole cell fatty acid profiles. Adult earthworms and bulk soil were collected from a mixed grass-legume hayfield (loamy, mixed, frigid Typic Endoaquent, pH 6.0, 28 g C kg⁻¹). Adult earthworms were dissected aseptically, the intestinal tract was divided into 3 parts (midgut, hindgut and proctodaeum) and three replicate samples of each gut compartment (aprox 200 mg dry weight basis) were extracted for total lipids. Samples from earthworm muscle, gut wall and bulk soil (2 g dw basis) were extracted in the same way. After transmethylation the resulting FAMES were analyzed by gas chromatography-FID.

The total FAME content was about 200 times higher in the earthworm gut than the bulk soil, and the biomass of specific biomarkers was 400- to 800-fold higher for bacteria and 100- to 275-fold higher for fungi. Gut samples contained more than one hundred FAMES in total, but only 28 FAMES were found in all gut compartments and the bulk soil. The 3 FAMES found only in bulk soil made up 18% of the whole fatty acid weight, but the FAMES found only in gut compartments (4 for midgut, 13 for hindgut and 5 for proctodaeum) accounted for less than 5% of the total FAMES weight. Multivariate analyses of the FAMES indicated that significant changes in the microflora community structure occur in the gut of *L. terrestris*. Fatty acid profiles of earthworm body wall and gut wall evidence complex trophic relationships within the gut system.

Our results provide new light for understanding the earthworm-microorganisms relationships and how earthworms may alter the microflora community structure in the soil system.

Bioengineering of Oligochaetes in rice agroecosystem

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More than half of world's population depends on rice, which is grown on nearly 150 million hectares of land comprising wide spectrum of land use pattern such as hill slopes, upland and lowland areas spread over either rain-fed or irrigated conditions maintained on traditional or conventional agrotechnology. Traditional rice agroecosystems have been extremely sustainable but unable to meet the projected demand of 760 million tons by 2020 indicating an increase of about 65% over present level. At the same time conventional agrotechnology has only been successful for temporary yield enhancement but is associated with unsustainable production, decrease use efficiency of agrochemicals resulting serious environmental and human health problems. While yield enhancement is a necessity to the growing food demand of 21st century, it should not be at the expense of future generation, nor should it ignore the concept of sustainability.

Agricultural practices that need to maintain sustainability of the rice producing environments will require an increased knowledge of the ecology of these ecosystems with emphasis on mutualistic relationships. The present review is based on the status and strategies of Oligochaetes in rice agroecosystems emphasising the bioengineering activity of different functional categories of dominant Oligochaetes. Broad categories of Oligochaetes available in rice agroecosystems of India belong to tubificidae, moniligastridae, almidiae, ocneroдрilidae, and megascolecidae.

This study includes biogeographical distribution of species, population dynamics, biological strategies and life cycle pattern. Bioengineering activity of some dominant Oligochaetes in rice agroecosystems highlights their role in the following aspects of interaction studies on:

- (i) their contribution to the physical habitat in maintaining oxidising atmosphere and their possible role in reducing methane production,
- (ii) their impact on micro food chain level with microbiota and nematodes,
- (iii) their feeding relationships with plant parasitic nematodes and weed seeds for their control,
- (iv) their worm cast production and enhancement of soil fertility
- (v) their activity with organic matter quality and impact on plant production.

It has been emphasised for wider international efforts to understand rice agroecosystem ecology, their biological monitoring and management through a transitional approach for maintenance of economic production and ecological conservation.

Does epigeic arthropod macrofauna modify soil physico-chemical properties?

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Little is known of the impact of mobile epigeic macroarthropods on soil physico-chemical properties. The impact of large invertebrates, litter and root ingrowth on accumulation of organic matter and on physico-chemical properties of soil (carbon and humus content, total sorption capacity, porosity and macroaggregate mass) was studied in 20-month field experiment in mesocosms. Steelon-screen enclosures were filled with poor substrate (sand with clay) and placed in a meadow soil profile. Litter bags containing grass (*Dactylis glomerata*) leaves and stems were placed inside enclosures on the surface of the substrate. Twelve treatments were applied in which mesocosms open (O) and closed (C) for fauna penetration differed in the presence (+) or not (-) of litter (L) and root ingrowth (R). Pitfall traps for recording fauna mobility were placed in +R mesocosms.

The biomass of total fauna was greater by 11 and 9.6 times in O to C series in +R and -R mesocosms respectively. The mass of arthropods' remains was higher by 2.63 times (0.21 – 0.38 g dry w. m⁻²) in O than in C series. Acridids' faecal pellets (0.013 g dry w. m⁻²) were found only in accessible for fauna +R treatment. Mass of earthworms in traps and soil and their casts (the latter were found only in five of 42 +R and any in 10 of -R series) were negligible and thus it was assumed that their role in experimental treatments was not important.

The top sand layer (0-5cm) in +L+R mesocosms had significantly lower field bulk density (by 11.3%) and higher by 17.8% total and by 110.6% non-capillary porosity comparing to -L+R series, but any significant differences between O and C series were found. Significantly higher (by 5.7 times) was the mass of macroaggregates of > Ø 1mm in surface layer (0-1cm) of +L+RO than in +L+RC series in the second year of the experiment. Total sorption capacity in +L-R treatments was significantly higher (by 40,1-45,4%) than in -L-R series while in +R treatments differences were not evident. In -R treatments accessible for fauna, both +L and -L series had significantly higher sorption capacity (by 14%) comparing to C series. Open +L had significantly higher humus acid Carbon content (by 61.4%) than closed ones. Clearer differences between O and C treatments were seen in the case of -R mesocosms. In chemical analyses, 11 parameters of 15 analysed tended to be of higher values in open +L-R treatment than in +L-R closed ones, while in the case of +L+R mesocosms only 6 of 15 respectively.

These results imply that mobile epigeic macroarthropods' fauna contributes to soil physico-chemical characteristics by promoting aggregate formation, increasing stable humus fraction and nutrient content. Fauna impact on soil properties should be analysed in experiments with greater surface area than in microcosms.

Physical properties of earthworms casts (*Andiorrhinus sp.*) and termite mounds' wall in northern pastures of Brasil (Para)

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Earthworms and termites are generally considered as ecosystem engineers who played an essential function in the bioturbation of soil . The casts and the termite mound they produce are recognised to have a great importance in the regulation of soil processes. A fire practiced in these Brazilian pastures is also documented as a great disturbance of the ecosystem. The physical stability of earthworms' casts and termite mounds' wall was compared before and after fire into tree recent pastures of Amazon. A granulometry , a clod porosity measure, a test of structural stability and a test of rain simulation were realised on several parts of various casts and on 3 parts of termite mounds' wall of each pasture. All measures were also realised on burnt structures. Even if casts were different from termite characteristics, all the structures were extremely compact and stable more than a neighbouring soil. A stability of earthworms' casts was comparative to termite mound's wall. The pastures' fire did not increase a fragility of the biogenic structures. So an addition of various attacks (crushing, raining, burning) seemed to succeed to degrade the biogenic structures.

Spatial and temporal distribution of biogenic structures and vegetation component (clumps, trees, burnt trunks) in forests and pastures of Northern Brazil (Para)

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Soil fauna activity is one of the greatest factors influencing soil processes. One aspect of this activity is the production of biogenic structures such as earthworm casts left on soil surface. A comparative analysis of spatial and temporal distribution of biogenic structures and vegetation component was realised in 4 pastures and 3 forests on the deforestation front of Amazonian forest. In each location, 50 m² were sampled (5x10m). These 50 m² were divided into 50 squares of 1*1m. In each little square, all biogenic structures and vegetation components were mapped. This work was realised in the middle of rain season in 2002 and 2003 and the production of biogenic structures on soil surface was monitored during 2 months. An experiment on the production of earthworm casts was also carried out, two factors being studied, i.e. the quantity of litter in forests and the presence-absence of *Braccaria sp.* clumps in pastures. More than 90% of the sampled structures were earthworm casts (*Andiorrhinus sp.*). The density of earthworm casts was 15.4 items m⁻² in forests and 2.2 items m⁻² in pastures. The spatial distribution of earthworm casts seemed to be aggregated in pasture whereas in forest the distribution seemed to be homogeneous. More earthworm casts were found near burnt trunks and middle size *Braccaria sp.* clumps. Moreover their production was more important where the soil was more covered by vegetation. All these results allow making preliminary hypothesis on earthworms cast effects on surface soil processes.

Metabiotic activity of earthworms affects patterns of microbial succession in plant litter

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Earthworms and other large saprophagous soil invertebrates redistribute, fragment, and bury great amounts of plant litter, thereby strongly affecting litter decomposition process. However, the impact of this metabiotic (~'engineering') activity on the species composition, abundance and succession of litter-decomposing microorganisms is poorly understood. The purpose of this study was to quantify the effects of metabiotic (creation of middens) and direct feeding activity of anecic earthworms *Lumbricus terrestris* L. on the community composition and succession of yeasts on decomposing *Tilia* leaves.

Field experiment was carried out in a mature lime (*Tilia cordata*) stand on soddy-podzolic soil situated ca. 30 km south of Moscow (Russia). *L. terrestris* are very abundant at the site, and a large proportion of *Tilia* litter is collected in middens at the entrances of *L. terrestris* burrows, where it is eventually consumed by earthworms and associated soil fauna.

The following substrates were analysed: green *Tilia* leaves (i), *Tilia* litter at different stages of decomposition, either unaffected by earthworm activity (control, ii) or collected from *L. terrestris* middens (iii), contents of *L. terrestris* gut (iv), *L. terrestris* casts (v) and uppermost mineral soil (vi). Samples were collected in September, October, November, December and April. The abundance and taxonomic structure of yeasts were estimated by serial dilution and plating on acidic malt-extract agar.

Control *Tilia* litter, litter from middens and *L. terrestris* casts differed considerably in the composition of yeast community. In litter and in soil humic horizon eurytopic basidiomycetous yeasts *Cryptococcus albidus*, *C. laurentii*, *Sporobolomyces roseus* and *Rhodotorula glutinis* dominated. In contrast, yeastlike ascomycetes *Pichia segobiensis* and *Blastobotrys* sp. prevailed in middens. Successional patterns of the yeast communities were compared using canonical analysis. At the early stages of decomposition, yeast communities in control litter and litter from middens had similar taxonomic composition. The difference between communities increased in November, reached maximum in December, and then decreased again in April. The overall abundance (CFU) of yeasts in *L. terrestris*-affected and control litter was not significantly different.

The abundance of yeast was low in the intestines of *L. terrestris*. Yeastlike fungus *Blastobotrys* sp. and ascosporeous yeasts *Williopsis saturnus* were the most abundant species in *L. terrestris* gut contents and fresh casts. Likely, these species are resistant to digestive enzymes. Other yeast species were very rare in samples from earthworm intestines, presumably due to quick lysis of cells. The abundance of *W. saturnus* in earthworm guts is surprising, as this species seems to be a typical pedobiont.

We conclude that metabiotic activity of *L. terrestris* may considerably affect patterns of microbial succession in decomposing leaf litter, though in our case similar final stages of succession were reached in *L. terrestris*-affected and control litter. On the other hand, feeding activity of *L. terrestris* constantly creates microhabitats (intestines and casts), which harbour very specific communities of microorganisms.

SESSION 5

Food Webs and Other Nested Biological Controls

ORAL CONTRIBUTIONS

Mitigation of nematode community pathogenicity by plant-parasitic nematodes in tropical regions

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In tropical and subtropical regions most plants are attacked simultaneously by several species of nematodes. For example, soil samples collected from the root zone of sugarcane in Ivory Coast, Chad, Burkina Faso and South Africa contained in average 7 (range 3 to 12) genera of plant parasitic nematodes. Nematode species are considered as a problem on a particular crop based on a combination of their prevalence, average density and their reputation as pathogens of other crops. Their pathogenicity is usually measured in pot experiments in which each species is inoculated separately on the plant. In such experiments, all species were usually found highly pathogenic.

In sugarcane fields there is usually a wide variation in growth, even over short distances. In a study site in South Africa it was demonstrated that such variability was attributable to the distribution of the nematode communities, and not, as is normally expected, to variation in the physical and chemical characteristics of the soil. The same five plant-parasitic nematode species were present over the entire study site and the number of individuals was similar. However, in areas of poor growth, *Meloidogyne* and *Xiphinema* dominated the nematode community, whereas where growth was better *Helicotylenchus* and *Pratylenchus* were dominant. After subjecting the data to principal component analysis the correlation between biomass and the factor that described the entire nematode community was better than that for any one of the species taken in isolation. This result suggested that the distribution of the good as well as the poor growing areas could be explained by the composition of the nematode communities. These results further suggested that damage to plants might not be related to the number of plant parasitic individuals *per se*, but rather to the species composition of the nematode community. Increasing nematode diversity, by encouraging less pathogenic species to replace those that are more pathogenic, could reduce the overall pathogenicity of the community. This alternative method of control, unlike the use of plant resistance or nematicide treatment, does not create any selection pressure or ecological vacuum, neither of which is desirable. From the agronomic point of view, the goal is not to gain the maximum, but to lose the minimum on a sustainable basis.

Another avenue to explore is the identification of genes that confer susceptibility to a mitigating species, such as *Helicotylenchus dihystra* in sugarcane. A plant bearing this kind of gene would grow in the presence of nematodes, like a tolerant plant except that this “directed tolerance” would not increase the number of pathogenic nematodes. Also unlike resistant or conventionally tolerant cultivars, it could be used to advantage everywhere, even when a damaging community is not present. The sustainability of this option is ensured because it is not possible, unlike resistance, to break down susceptibility.

A simple and rapid method for labelling soil animals with ¹⁵N and ¹³C

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Stable isotope tracer techniques provide a powerful tool for investigations of the ecophysiology and role of soil invertebrates in soil C and N cycles. However, techniques for labelling soil animals described in the literature involve the feeding of isotopically enriched plant material, the production of which is time-consuming, expensive and reliant on specialized equipment. Here, we describe a novel simple, rapid and cost-effective laboratory method for labelling earthworms and slugs that can circumvent the production of labelled plant food by using isotopically enriched chemical compounds which are commercially available.

Soil-feeding earthworms, *Aporrectodea caliginosa* (Oligochaeta, Lumbricidae), were labelled as follows. Sieved mineral soil was amended with ¹⁵NH₄⁺ together with unlabelled glucose (C/N ratio = 4) and incubated for 7 days to facilitate the incorporation of ¹⁵N into the soil organic N pool. Then, earthworms were provided individually with 4 g of the pre-incubated soil and enriched ¹³C₆-U-glucose was added as a solution. The labelling period was 4 days. The labelling efficiency was 16% and 10% for ¹⁵N and ¹³C, respectively. Subsequently, the ¹⁵N and ¹³C label was traced in the body tissue and cutaneous mucus of *A. caliginosa* for 21 days. The disappearance of label in mucus was best described by a two-term exponential function, whereas the label loss in body tissue followed a single-term exponential function.

Terrestrial slugs, *Deroceras reticulatum* (Gastropoda, Agriolimacidae) were labelled in a similar fashion by providing them with a mixture of wheat bran, ¹⁵N enriched lettuce powder and ¹³C₆-U-glucose. Labelling efficiencies in this experiment lasting 15 days were 27% for ¹⁵N and 24% for ¹³C.

A new DNA-based method to disentangle trophic relationship within soil fauna communities

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The knowledge of trophic relationships is a fundamental component of any attempt to describe how natural communities are structured or how complexes of species interact. Regarding to pest control a better understanding of trophic interactions means that a scientific basis underpinning the design of sustainable regulation strategies can be achieved. The most reliable way to investigate pest-predator interactions are studies conducted directly in the field. However, many trophic interactions are difficult to observe because of the smallness of the species involved, extra-oral digestion of predators and/or their hidden mode of life, which is especially true for interactions among soil animals. Recently DNA-based methods have shown their great potential for analysing trophic relationships under such difficult circumstances. Compared to the stable isotope approach this method provides information on species-species interactions.

In this project we aim to identify the key invertebrate predators of *Melolontha melolontha*, *M. hippocastani*, *Aphimallon solstitiale* and *Phyllopertha horticola* (Coleoptera: Scarabaeidae) by a DNA-based approach, to our knowledge the first time this technique is used for investigating trophic interactions within a soil fauna community. The larvae of these scarab species cause severe damage in grassland, arable crops and forests throughout Europe. There is strong evidence that predatory soil dwelling arthropods are capable to regulate scarab populations, but the predator guild of the above mentioned species is poorly known to date. To identify the key predator species we use a two step approach: (1) Developing a PCR-based method to identify prey DNA within predator guts and (2) screening of field caught predators for DNA of the scarab species. In the first step COI and COII sequences were analysed to design prey-specific primers. *Poecilus versicolor* larvae (Coleoptera: Carabidae) were fed with larvae of each prey species to evaluate the primers and to optimise PCR-conditions. Furthermore extensive feeding experiments with scarab eggs and larvae were conducted to assess prey DNA detection period. These experiments are currently analysed. Carabids were also fed with dead scarab larvae to determine the probability of detecting carrion consumption. Distinguishing between scavengers and predators is important as only predators are relevant for natural pest control. In the second step predatory soil arthropods are collected in grassland ecosystems, to identify the key predators of these scarab species.

Stable isotope analysis of soil macrofauna along an abandoned rice field chronosequence in northeastern Argentina

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The study site in Corrientes, northeastern Argentina, had been used for cattle ranching on natural grassland vegetation dominated by *Andropogon lateralis* (C4 plant), then cultivated with rice (C3 plant), and are now at different stages of abandonment because the cost/benefit becomes unfavorable after four cropping cycles. After the abandonment of irrigated rice fields, the density of anthills of an ant (*Camponotus punctulatus*) have unexpectedly increased, exhibiting 2400 anthills ha⁻¹ in three years after being abandoned (Folgarait et al. 2002). Thomas (2001) has shown that species diversity of soil macrofauna increased along the chronosequence. To investigate the soil-food web structure after the abandonment of irrigated rice fields, we analysed carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) stable isotope ratios of ants (*C. punctulatus* and *Solenopsis* spp.), termites and earthworms along the chronosequence after being abandoned.

$\delta^{13}\text{C}$ values of aboveground vegetation have confirmed that C3 herbs existed in early stages after abandonment but C4 grass dominated in later stages. $\delta^{13}\text{C}$ of soil organic matter changed with delay after $\delta^{13}\text{C}$ of vegetation changed from “C3” to “C4” values. $\delta^{13}\text{C}$ values of *C. punctulatus* followed the changes in $\delta^{13}\text{C}$ of vegetation, whereas $\delta^{13}\text{C}$ values of an endogeic (soil-feeding) earthworm were close to $\delta^{13}\text{C}$ of the soil organic matter, showing the time-lag between grazing- and detritus-food webs.

Trophic position inferred by $\delta^{15}\text{N}$ values among animal groups were almost constant along the chronosequence, except for *C. punctulatus* in one plot (P1: 2 years after abandonment). *Solenopsis* spp. (fire ant) had significantly higher $\delta^{15}\text{N}$ values than *C. punctulatus*, suggesting their carnivorous feeding habit. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values in earthworms and in termites suggest that the litter-feeding (epigeic) earthworms consumed more decomposed materials than litter-feeding termites (*Nasutitermes fulviceps*) but the soil-feeding earthworms and termites (*Aparatermes abbreviatus* and *Anoplotermes* sp.) consumed the materials at the similar decomposition stage.

Stable isotope analysis has shown the different responses of the different soil macrofauna groups on the disturbance.

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Arbuscular mycorrhiza and collembolans interact in affecting community composition of saprotrophic fungi

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Plant roots compete with saprophytic soil microorganisms for nutrients, and in many cases microorganisms are superior competitors. A mutualistic association with mycorrhizal fungi is the most common way by which plants increase their competitive ability and increase nutrient acquisition. The interaction between two main functional groups of soil fungi, i.e. saprotrophic decomposers and biotrophic mycorrhizal fungi are of great importance for carbon and nutrient turnover in soils. Besides other factors, the outcome of these interactions may depend on the activity of soil animals, especially of fungal feeders like collembolans and nematodes. However, our knowledge on the interactions between plants, mycorrhiza, saprotrophic fungi and fungivorous soil organisms remains extremely poor.

In a two-factorial 200 days-long laboratory experiment we assessed the effects of collembolans (a mixture of 3 species was used, i.e. *Protaphorura fimata*, *Heteromurus nitidus* and *Folsomia candida*) and arbuscular mycorrhiza (AM, *Glomus mosseae*) on the composition of saprotrophic microfungi (SF) in soil planted with invasive C4 grass *Cynodon dactylon*. Effects of experimental treatments on the plant growth, nutrient (C, N, P) availability, microbial activity, and collembolan populations were also examined. Species composition of the fungal community was analysed using the modified washing and plating method. Fungal communities were compared using multidimensional scaling and discriminant analysis.

The presence of AM reduced plant growth, though only 6-12% of total root length was colonized. Collembolans were not affected by AM. In spite of lower plant biomass in the microcosms with mycorrhiza, the availability of nitrogen and phosphorus were significantly higher in "no AM" microcosms. The presence of collembolans reduced microbial activity, total (AM+SF) length of fungal mycelium and number of AM spores. Collembolans reduced negative impact of AM on plants and increased P availability for saprotrophic soil microorganisms.

The presence of collembolans affected species composition of soil microfungi ($p < 0.05$), mainly due to the increase in relative abundance of dark-pigmented fungi like *Cladosporium* and *Ulocladium*.

The effect of AM on the composition of SF community was very pronounced ($p < 0.03$), but in microcosms with collembolans only. In particular, AM strongly reduced the relative abundance of *Trichoderma harzianum* and *Penicillium restrictum*, but increased the occurrence of *Ramichloridium schulzeri* and several sterile forms. The effect of AM on SF was not significant in microcosms without collembolans ($p = 0.22$). We therefore conclude that the interactions between mycorrhizal and saprophytic fungi depend on the activity of fungivorous animals. Possible mechanisms of this phenomenon are discussed.

Predation on bacteria by bacterial-feeding nematodes and consequences on the structure of the soil microbial community

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Bacterial-feeding nematodes are, with protozoa, the main grazers of soil bacteria. An adult bacterial-feeder ingests about 10^6 bacterial cells a day. Interactions between these bacteria and nematodes have important repercussions on soil functioning and particularly on nutrient availability. Our experiments had the objective of determining if bacterial-feeding nematodes select the soil bacteria they ingest. We were also interested in analyzing the consequences of their feeding behavior on the structure of the soil microbial community but also on nutrients availability for plant growth.

Nematodes were inoculated to nutrient agar Petri dishes in which individual bacterial strains had been previously grown or in soil containing a complex microbial community. In vivo studies conducted in the presence of single bacterial strains showed that the type of ingested bacteria conditioned the development of the different bacterial-feeding nematode species tested. Besides, the activity of nematode modified the structure of the soil microbial community. The soil microhabitat that was most influenced by the nematode was the soil in contact with the macroporosity. Moreover, the impact of nematode grazing on the overall soil microbial community seems to primarily affect microbial activity and relative dominance rather than microbial diversity. Finally, nematode activity led to a significant decrease in microbial biomass and density of culturable bacteria, however, nematodes stimulated bacterial activity.

SESSION 5

Food Webs and Other Nested Biological Controls

POSTER CONTRIBUTIONS

Meta-analysis of natural abundance stable isotope ratios in earthworms

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Soil fauna, and in particular earthworms, play an important role in soil fertility and nutrient dynamics, and therefore any variation in their feeding activity could have important implications for biogeochemical cycles. In this context, novel isotope techniques have proved to be powerful research tools for establishing food preferences and resource partitioning among soil invertebrates in general and earthworms in particular.

Here we review recent developments in the application of natural abundance carbon (C) and nitrogen (N) stable isotope ratio techniques in investigations of the ecological diversity and functions of earthworm communities. From the available literature it is concluded that most of the earthworm C and N nutrition is derived from recent residues and organic matter inputs, and that natural abundance isotope techniques are useful in investigating the changes in the feeding behaviour of earthworm populations both in natural and agroecosystems. However, variations in the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ spacing between earthworms and their food sources have been observed across different habitats and sampling periods and in response to physiological and biological changes which can obfuscate simple interpretations.

Ecological groups of earthworms comprise different species which obtain their nutrition from similar sources. Most studies found that tissue $\delta^{15}\text{N}$ values of earthworms reflect ecological groupings with the highest $\delta^{15}\text{N}$ values observed in endogeic species, followed by anecics and epigeics. However other authors argued that this functional classification is the result of habitat diversity and not related to different feeding activities. To clarify this issue, this review presents a meta-analysis of published N isotope ratios recorded for different earthworm species at different sites and geographic locations. The analysis revealed that N isotope ratios of endogeic worms were clearly distinct from those of the other ecological groups, showing a significantly higher enrichment in the endogeic, soil-feeding group than in guilds that feed mainly on plant litter. In addition, the analysis detected significant differences between epigeic, epianecic and anecic worms with the latter having the lowest N isotope values. Even when the worms were classified according to age groups endogeic species had again the highest ^{15}N enrichment in both mature and immature worms.

In conclusion, natural abundance stable isotope techniques are one of the most promising tools for determining how earthworm populations and other soil invertebrates respond to environmental changes at both temporal and spatial scales. They can supply novel, independent information about key organisms and key functions in a wide range of habitats and climates. Therefore, they can potentially also be used to evaluate the response of soil ecosystems to perturbation and to provide an estimate of human effects on ecosystem structure and function.

Soil algae as a carbon source for soil animals

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While it is well documented that soil algae and other photoautotrophic microorganisms can be important carbon sources in soils in extreme climatic regions, few studies have investigated algal carbon inputs into soil food webs in temperate regions. Soil algae are also commonly assumed to be a food source for several different soil invertebrate groups, but there is little experimental evidence to support this assumption. The objective of the present study was to test experimentally, using a ¹³C tracer approach, whether soil algae can act as a carbon source in temperate soils for common soil animals, namely earthworms (Oligochaeta), slugs (Gastropoda) and springtails (Hexapoda).

Mineral topsoil with visible algal growth was collected from two habitats in Ireland, a spruce forest and an arable field, and transferred into glass containers (1 l volume). A ¹³CO₂ enriched atmosphere was created in the sealed containers by releasing ¹³CO₂ (99 atom%) from NaHCO₃. The initial ¹³C enrichment was 74% at a concentration of 1300 ppm. Containers were incubated for 12 d at 20°C, either under artificial light conditions at an irradiance of 300μE (12 h cycle) or in the dark (additional control treatment to assess non-photosynthetic ¹³CO₂ fixation). Following incubation, the soil was either mixed or left undisturbed. Then, three groups of animals were introduced, earthworms (*Allolobophora chlorotica*), slugs (*Deroceras reticulatum*) and springtails (*Ceratophysella denticulata*), and incubated for a further 7 d. Animals were analysed without gut contents to assess assimilated ¹³C in their tissues.

Neither soil nor animals were significantly enriched with ¹³C in the dark-incubated treatments compared with unlabelled controls. While earthworms and springtails were highly ¹³C enriched in the treatments incubated under light compared to unlabelled controls, neither adult nor newly hatched individuals of the slug *D. reticulatum* were labelled. These results demonstrate that earthworms and springtails ingested algal material and assimilated ¹³C from it while slugs, contrary to a common assumption, did not. The endogeic earthworm, *A. chlorotica*, was more highly enriched in ¹³C when the soil had been left undisturbed than in the treatment where the algal material had been mixed into the soil, deriving 2.1% and 0.6%, respectively, of its total body carbon from the new algal carbon source in 12 d. This suggests that *A. chlorotica* grazed the soil surface selectively to feed on algae under the experimental conditions. It is concluded that soil algae can be a carbon source for food webs in temperate soils.

Is *Hormogaster elisae* (Oligochaeta, Hormogastridae) a predator of mites and springtails?

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Several authors (Dash *et al.*, 1980; Maraun *et al.*, 1999; Migge, 2001) have reported the negative relationship between earthworms and microarthropods; the very same has been reported for *Hormogaster elisae* (Álvarez, 1977) at El Molar (Madrid, Spain) by Gutiérrez *et al.*, 2003. One of the hypotheses proposed for explaining this is that earthworms might be predators of microarthropods: some authors have found the remains of their cuticles in the digestive tracts of different earthworm species (Dash *et al.*, 1986). However, McLean and Parkinson (1998) indicate that the active or passive consumption of microarthropods is insufficiently demonstrated, and that it seems improbable this should be the main mechanism determining relationships between these groups.

To determine whether *H. elisae* actively or passively preys upon microarthropods, the fresh casts and intestinal contents (from the anterior, mid and posterior intestine) of *H. elisae* were analysed. Both casts and intestinal contents were stained with Rose Bengal and were studied by filtering them through 45-50 µm meshes and by separation with n-heptane.

The intestinal contents contained mineral particles and plant remains (small roots, plant fragments and seeds), but no whole or fragmented arthropods were found in any part of the intestine. Only in one case was a springtail Poduromorpha found in the gizzard. The ingestion of microarthropods by *H. elisae* is therefore sporadic and probably accidental, the earthworm taking in these animals as it ingests soil.

The fresh casts provided similar results, although these contained a number of mites, springtails and some nematodes, as well as other organic material that became stained Rose Bengal but was hard to identify. It is likely, however, that these casts were colonised by microarthropods after their deposition, perhaps because of their richer organic content.

Food competition between *Hormogaster elisae* (Oligochaeta, Hormogastridae), mites and springtails. Preliminary results

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Gutiérrez et al. (2003) reported the negative effect of the earthworm *Hormogaster elisae* on microarthropods at El Molar (Madrid, Spain). This could be due to competition for food, predation or other causes. This paper examines the possibility of food competition between earthworms and microarthropods.

Microcosms were constructed from plastic boxes and filled with soil at 20% moisture. In the centre a cage made with 2 mm mesh was placed. The cage allowed microarthropods to move freely but restricted the movement of earthworms to within the cage. The soil of the cage was enriched with soil sieved to 0.2 mm or with homogenised topsoil (first 3 cm) to increase the quantity of organic matter. Controls were set up with earthworms either present or absent from both microcosm compartments.

The microcosms were kept at 15°C for 21 days before being dismantled and the microarthropods extracted by the Berlese-Tulgren method. They were then identified to the lowest taxonomic level possible and counted. The data obtained were subjected to analysis of variance (ANOVA) after verifying their normal distribution using the Shapiro–Wilks and Kolmogorov–Smirnov tests. Position in the microcosm (inside or outside the cage) was used as the independent variable.

In the microcosms enriched with soil sieved to 0.2 mm, nearly all the microarthropods left the cage – escaping the earthworms - despite it containing extra organic matter. In the controls, no significant differences were seen between compartments suggesting that these particles are not used as a food source by microarthropods.

In the microcosms enriched with homogenised topsoil, the microarthropods were just as numerous in the compartments with and without earthworms. This shows that this material nullifies the negative effect of earthworms on microarthropod numbers. The soil horizons closest to the surface might provide food resources used by both groups - for which they compete. Only juvenile oribatids escaped from the cage, showing them to be more sensitive to the perturbations caused by earthworms

The density effect of the periodical swarming millipede, *Parafontaria laminata* on soil food web

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The outbreak of arthropods often happens in various terrestrial ecosystems. There are many studies on the outbreak of herbivorous insects, however there are few studies on relation between outbreak of soil macro-fauna and soil food web. The train millipede (*Parafontaria laminata* (Attems, 1909)) is known for the swarming of high density population. The swarming occurs 8 years cycle. The larval millipedes eat soil, and the adult millipedes eat soil and litter. Due to the high density and biomass, the millipede may influence a soil food web structure.

We observed the millipede and soil macro-fauna density and biomass from 1997 to 2002 in central Japan. The train millipede swarming occurred in 2000. The relation between the train millipede and other soil macro-fauna was analysed by Principal Response Curve method and Principal Component Analysis (CANOCO). This investigation aimed to elucidate an influence by the population of high density and biomass of the train millipede on the food web of soil macro-fauna.

In 2000, total biomass of the macro-fauna except the train millipede ranged 0.2 ~ 1.3 g dry wt m⁻², whereas the biomass of the train millipede alone ranged 11 ~ 311 g dry wt m⁻². The biomass of millipedes except for the train millipede decreased along with the biomass of the train millipede in high density site of the millipede. There was no difference with the community structure of the soil macro-fauna at four sites where the density of the train millipede was different. Araneae (predator) increased along with the time-course increase in the density of the train millipede. However, the biomass of the train millipede was several times higher than other soil macro-fauna. Since the millipede have strong defensive substance, birds and mammals don't eat the millipede.

The train millipede was dominant in the soil macro-fauna. Therefore, the millipede seemed to have escaped from the influence of other macro-fauna. The swarming age millipede (7th instar and adult) eat litter and soil. Even at the highest biomass site, the not all of the litter was eaten. Therefore, the population density of the train millipede was not saturated to food. The reason why high density population has been established is not known. However the availability of food and few predator pressure seem to enable the existence of the high density of the millipede.

Experiments on a carnivorous tardigrade chasing bacterivorous nematodes

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Little is known about the complex dynamics of species interaction in soil food webs. In the present study, the carnivorous *Macrobiotus richtersi* (Tardigrada, Macrobiotidae) was presented with nematode prey (*Acrobeloides nanus*, *Pelodera teres*) to assess its importance as predator of nematodes in the soil food web. Firstly the experiments were conducted under simple, artificial conditions on a stiff agar film. Secondly the validity of the results was tested under more natural conditions in mesocosms with sand.

We investigated the tardigrade's functional response to the parameters: prey density, prey size, prey species and environmental condition (2-dimensional agar surface versus 3-dimensional sand microcosms). In the artificial system, a single adult tardigrade consumed nematode prey with up to 4.6 µg in four hours, that is 43 % of its own body mass. Predation rate was positively correlated to prey density, until at high densities a maximum rate was reached, where handling of prey needed all the time. As the handling of prey needed longer for bigger prey, maximum consumption rate decreased with increasing prey size. Still, the optimal prey of the present investigation was the biggest nematode prey, as it brought highest feeding value, that is biomass uptake per time. Nematode species reacted differently onto attack. Even on pure agar, where the nematode agility was very limited, vigorous undulation reaction of *Pelodera teres* led to a measurable reduction in consumption rate.

Mesocosm experiments with sands of different particle size demonstrated that *Macrobiotus richtersi* is able to chase and consume small bacterivorous nematodes in a three-dimensional soil matrix. However, consumption rate of sand mesocosms was significantly reduced compared to pure agar. The sand matrix improved nematode agility and possibly presented small pores as refuges to the nematodes. Impacts of predatory tardigrades on nematode numbers in the field are discussed.

Application of radiocarbon analysis to the ecological studies on termites

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Termites (Isoptera) are superabundant detritivorous animals in the tropical terrestrial ecosystems, and play an important role in decomposition processes through utilizing a various stages of organic matter ranging from fresh plant materials to humified material (soil organic matter). These abilities largely lie in the sociality and the symbiosis with microorganisms.

Stable carbon and nitrogen isotope ratios have been utilized to evaluate feeding habits of termites. These studies indicate that soil-feeding termites are more enriched in ¹⁵N compared to wood- and grass- feeding termites and propose ¹⁵N as an indicator of the functional position of the feeding habits in the humification process.

In this study, we applied radiocarbon analysis to the ecological studies on termites as an indicator of feeding habits, which should reflect the average age of carbon (C) the termites utilize. We collected termites from grass savanna and gallery forest in Lamto Ecological Research Station, Ivory Coast and measured the ¹⁴C content by accelerator mass spectrometry. A grass-feeding termite, *Trinervitermes geminatus*, resembled the current year grass in ¹⁴C. Wood-feeding termites, *Microcerotermes parvus* and *Cryptotermes brevis* showed different ¹⁴C content and the former species had lower ¹⁴C content, which indicate an average age of C at least 5 years old. A soil-feeding termite *Noditermes aburiensis* was similar in ¹⁴C to the wood-feeder termite, *M. parvus*, but had higher ¹⁴C content compared to a soil-feeding termite, *Amitermes evuncifer*. These results suggest that ¹⁴C could characterize the termites along with the C age gradient, independent of the known feeding habits, indicated by ¹⁵N

The importance of soil microbial loop in plant recovery from aboveground herbivory

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In grazed grasslands, plant recovery from leaf tissue removal is a key process affecting resource availability to aboveground grazers. Shoot mass recovery depends on soil nutrient availability, which is affected by soil trophic interactions, such as the soil microbial loop. We established a greenhouse experiment using *Phleum pratense* seedlings and soil collected from grazed grassland to test whether plant shoot removal activates the soil microbial loop, i.e. increases the abundances of soil microflora and their grazers in the plant rhizosphere. To investigate whether the activation of the soil microbial loop in turn leads to enhanced plant N acquisition from decaying organic material, we added ¹⁵N-labelled root litter into the soil before defoliation and traced the amounts of ¹⁵N in plants after defoliation. Moreover, to study whether soil fertility affects the importance of the soil microbial loop in plant recovery, we grew plants in two soil nutrient status. Plant shoot biomass, root biomass, N, ¹⁵N and C concentrations, as well as soil microbial biomass, root mycorrhizal colonization rate and abundances of nematode trophic groups, were determined at two harvest times to track the dynamics of plant performance, soil microflora and their grazers. Our preliminary results suggest that in contrast to our hypothesis, shoot removal did not activate the soil microbial loop or enhance plant N acquisition from decaying organic material.

Do mammalian grazers affect plant growth and plant quality via long-term soil feedbacks?

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Aboveground herbivores may have effects on soil organisms and processes directly for instance through nitrogen return and trampling or indirectly via plants. Soil biota is in turn known to be able to influence aboveground herbivores by affecting plant productivity and nutrient allocation. Therefore it is reasonable to believe that aboveground grazers may influence soil properties in a way that later affects the quantity and quality of their resources. In this study we tested whether mammalian grazing affects plant properties via long-term changes in grassland soil and, in a case such effect is found, what are the changes in the soil. In addition, we aimed at resolving the possible mechanism behind the grazing effect (i.e. defoliation, nutrient return or the physical presence of animals). In the first part of the experiment, four treatments were established in grassland: 1. grazing by cattle, 2. mowing of vegetation with slurry addition, 3. mowing of vegetation without slurry addition and 4. no management. After three growing periods, soil was collected from all treatment plots and soil inorganic N concentration as well as the abundances of soil organisms were measured. In the second part of the study, seedlings of *Phleum pretense* were raised in soils originated from different grassland management histories. To test, whether the release and availability of N from dead organic matter differs as a result of different management, ¹⁵N-labelled litter was added into the soils. After a 10-week growing period, *Phleum pretense* biomass and N, ¹⁵N and C concentrations were measured. Our results indicate that mowing alone was able to generate a soil feedback that reduced *Phleum pretense* shoot biomass and increased shoot nitrogen concentrations. Grazing by cattle resulted in a high variation in shoot production and compensated the negative effect of shoot removal in some instances. The completed analysis of results and discussion will be presented in the colloquium.

Isotopic fractionation in three trophic levels of the soil food web

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The isotopic trophic-step fractionation of three components of the soil food web was investigated in a laboratory experiment. The plant pathogenic fungus *Fusarium culmorum*, which was grown on natural and enriched isotopic abundance media, respectively, was fed to the fungivorous Collembola *Folsomia candida*. The juvenile Collembola was then fed to predatory mite *Hypoaspis aculeifer*. The enriched medium was enriched with the isotopes ¹³C, ¹⁴C and ¹⁵N.

The fractionation of isotopes of the organisms on natural and enriched media was measured on bulk biomass and the isotopic equilibrium after diet switch from natural to enriched diet and vice versa was investigated.

The study is still in progress and the results will be ready late spring this year.

Isotopic analysis of two contrasting agricultural soil food webs

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Natural abundance stable isotope ratio techniques provide a novel tool for the investigation of the feeding ecology of soil animals and trophic relations in soil food webs. Comprehensive analyses of soil food webs have so far only been conducted in forest ecosystems. As part of a large national Irish project on biodiversity and its functional significance in farmed landscapes (Ag-Biota), we have analysed a number of soil animal taxa in two contrasting farming systems, namely a pasture and an arable crop (barley). Isotope ratios of carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) were measured in selected animal groups, representing detritivore (earthworms, springtails), herbivore (slugs, aphids) and predatory (ground beetles, spiders) feeding habits, as well as soil, plants and plant litter. Patterns in the isotopic data will be compared with known feeding habits. The data will be used to assess the dependency of generalist predators on detritivore and herbivore food chains in the two systems. In addition, the dependency of generalist predators on detritivore prey will be quantified in the cereal system by exploiting the fact that, at time of sampling, the existing barley crop (C_3 plant) was isotopically distinct from the plant litter and youngest soil organic matter derived from the preceding maize (C_4 plant) crop.

Effects of preservation on the isotopic composition of soil invertebrates

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Natural abundance stable isotope ratio techniques are a relatively new tool in soil zoology. A number of technical difficulties need to be resolved before they can be exploited fully. Most importantly, sample preservation and preparation methods are required which will not alter the isotopic composition of soil animals prior to isotopic analysis. While some observations have been made (e.g. Schmidt and Ostle, 1999), a systematic study is needed to assess the usefulness of common soil zoological sampling and preservation methods. Similar studies have been published dealing mainly with various vertebrate animal groups (Sarakinos et al., 2002).

We conducted a series of experiments to test the effects of sampling, preservation and related procedures on the carbon and nitrogen isotopic composition of selected soil arthropods, namely spiders, ground beetles and springtails. Effects of pitfall trapping were assessed in terms of liquid used (water, acetic acid, formalin), duration of trapping (7 and 14 days) and temperature (8 and 18°C). Fresh, unpreserved beetles and spiders were compared with frozen, freeze-dried and ethanol-preserved animals. Springtails were analysed after freezing or preservation in either picric acid or monoethyleneglycol. Finally, the effect of the gut content on the isotopic composition of ground beetles and springtails was assessed by feeding live animals with an isotopically distinct food source and analysing them before and after gut clearance.

The results of this study will make it possible to select methods of sampling, preservation and preparation that are least likely to alter the isotopic composition of soil arthropods.

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Effects of grassland species diversity in a simple soil food web

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The soil food web and the processes that it regulates are influenced by the quality of resources that the plant community produces. These effects arise largely through differences in leaf and root litter quality and through differences in root exudation.

In order to investigate the feedback of the plant community to the soil food web more in detail, we set up a greenhouse experiment where we manipulated both, the diversity of a model grassland community, consisting of 43 common species of a Central European *Arrhenatherion* grasslands belonging to 4 different functional groups (grasses, small herbs, tall herbs, legumes) and the composition of the soil food web. The soil animal treatments were set up with earthworms, collembolans and earthworms + collembolans using two earthworm species (*Aporrectodea caliginosa*, *Lumbricus terrestris*) and three collembolans species (*Protaphorura fimata*, *Heteromurus nitidus*, *Folsomia candida*). After three months the experiment was destructively sampled and changes in earthworm biomass and abundance of Collembola were recorded.

We found that *A. caliginosa* lost biomass at low plant diversity levels and gained biomass in high plant diversity treatments. In the presence of Collembola, *A. caliginosa* also increased in biomass, therefore positive effects of plant species diversity were not detectable. In contrast to our expectations, plant functional groups had no effect on the biomass of earthworms but affected the abundance of Collembola.

These results indicate that feed-back effects of the plant community to the soil food-web are much more complex than previously assumed and may have a significant influence on soil processes.

Insect root herbivores, plants and microbes

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Despite the fact that root-feeding invertebrates are a major component of the soil biota in grassland ecosystems little is known of their role in ecosystem functioning. In a study at the NERC Soil Biodiversity site at Sourhope (Scottish Borders) we monitored population changes in the major root herbivores at the site *Tipula paludosa*, and cutworms (*Agrotis* spp.) in the Control (C), Nitrogen and Lime (NL) and Pesticide (P) treatments over a three year period. The regular application of the insecticide reduced the *Tipula* and cutworm populations after the first summer. There were no treatment differences between the C and NL plots. However, what was interesting was a switch in species dominance of the main root feeding species. At the outset of the study the most abundant were the Tipulids with populations in the order of 120 m⁻², over time the numbers declined to zero in the C plots. Conversely, the populations of the cutworms increased with time from zero in the first year to around 80 m⁻² by March 2002 (Figure 1). However, although there was a change in the dominant species, the function was maintained. There were no treatment differences (but there were temporal differences) in root turnover between the C and NL plots, but root turnover was significantly reduced in the P treatment, reflecting the reduced pressure on the plants from root herbivory by insects. In addition to the more obvious impact of root herbivory (i.e. removal of plant tissue) root feeding has a number of other more subtle effects, both on the plant and on the other members of the soil community. The detachment of large quantities of root material puts severe pressure on the plants and demands reallocation of resources for root maintenance and replacement. This is important in determining the fitness of individual plants with implications for plant diversity. Plant species richness was greater in the P plots than in the C plots and this may be a consequence of the removal of the root herbivores, particularly as the overall numbers of the major above ground herbivores (slugs) were not reduced by the pesticide.

The removal of large amounts of plant tissue by root herbivores increases the inputs to the detrital pool in the soil and provides an energy source for the soil micro-organisms. The soil microbial community is also influenced by changes in root exudation patterns, mediated by root feeding. This was demonstrated in a series of microcosm experiments, where changes in soil microbial communities were determined when *Tipula* were feeding on either *Agrostis capillaris*, *Lolium perenne* or *Trifolium repens*.

This project highlights the effects of root feeding in the Sourhope system and in grassland systems generally. Investigations of plant/ soil interactions are important when considering ecosystem processes, however, it must be remembered that root herbivory is the norm and its effects must always be taken into account in such studies.

Host location by larvae of *Sitona lepidus*

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One of the most significant pests of white clover (*Trifolium repens* L.) is the clover root weevil (*Sitona lepidus* L. Coleoptera; Curculionidae). The adult of this species feeds on the leaves of the plant. The early instars of the larvae feed within the N-fixing root nodules, but as the larvae grow they move out of the nodules and feed on progressively larger roots. It is still not clear that nodule feeding is obligative or facultative. This study investigated the ability of the root-feeding weevil, *Sitona lepidus*, to locate white clover (*Trifolium repens*) roots growing in the soil and to distinguish them from the roots of other species of clover and a co-occurring grass species. In experiments in which the weevil was given a choice of roots, we used a combination of invasive techniques and the novel technique of high resolution X-ray microtomography to non-invasively track insect movement in the soil towards plant roots. Burrowing distances towards roots of different plant species were also examined. Newly hatched *S. lepidus* (c. 1mm in length) recognised white clover roots and moved preferentially towards them when given a choice of roots of either subterranean clover (*T. subterraneum*), strawberry clover (*T. fragiferum*) or perennial ryegrass (*Lolium perenne*). In each paired test, 81% of responsive *S. lepidus* larvae chose white clover in preference to root-free soil, 80% chose white clover in preference to perennial ryegrass, 74% chose white clover roots in preference to subterranean clover roots and 68% chose white clover roots in preference to strawberry clover roots. Larvae recognised white clover roots, whether released in groups of five or singly, when released 25 mm (meso-scale recognition) or 60 mm (macro-scale recognition) away from plant roots. There was no statistically significant difference in movement rates of larvae, although there was a tendency to move more slowly (c. 20% slower) when burrowing towards roots of white clover than other species of plant.

Modifications of the foraging behaviour of earthworms related to different agricultural practices

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The earthworm species are classified in three major ecological categories: epigeic, anecic, endogeic (Bouché, 1977). This classification is based on morphological, physiological and ecological parameters, suggesting specific behaviours for each ecological category. However, some studies have shown the variability of behaviour within the different ecological groups (Jégou, 1998; Bastardie, 2003) and also within the species related to the environmental conditions (Jeanson, 1968). These studies, if they have improved the knowledge on earthworms' behaviour, have been realised under controlled conditions that can modify the behaviour of fauna. In another hand, these studies focalised under one or two earthworm species, ignoring the interactions which exist in natural conditions. The transfer of the knowledge obtained in laboratory to the natural conditions seems to be difficult.

In order to better understand the behaviour of earthworm, we carried a field approach. The earthworms' behaviour was assessing by the foraging activity. Moreover, taking into account the impact of agricultural practices on earthworms communities (Bostrom, 1987), the aim of this study was to assess the modification of earthworm behaviour submitted to different agricultural practices.

Investigations were conducted in western Brittany (France), in two pedological context (West and East of Brittany: granite and schist geological supports) and under three different agricultural managements (a continuous maize field, a rye-grass/maize rotation, an old pasture). Two databases were coupled: (i) the earthworm populations were characterised by their density, biomass and specific structure; (ii) at the same place, the macropores resulting from the earthworms' activity were quantified on the soil profile.

Our study shows that (i) the relation between the number of earthworms and the number of macropores is strongly influenced by the agricultural practices: the foraging behaviour is all the more important as food is weak, like under maize compared to pasture; (ii) within a same agricultural system, this relation is influenced by the specific composition, confirming the more important foraging behaviour of *A. giardi* compared with that of *L. terrestris*.

Protein sources for a detritial food web

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To understand mechanisms managed biomass partitioning in a detritial food web it is necessary to estimate sources of the main nutrients in it, firstly protein ones. To determine the relationships we reviewed available literature on biomass along a biome gradient from polar deserts to arid ecosystems and own data on protein content in different compartments of the web.

Microbial biomass is maximal in coniferous forests and animal biomass in forest-steppe ecosystems (oak stands and meadow steppes). However there is no coincidence in biomass distribution of different web compartments along the biome gradient.

Microbial biomass has the same trends as litter mass due to high proportion of fungi in microbial biomass in accordance with most of data. There is a significant correlation between animal and bacteria biomass, and fungi and litter biomass, but a low correlation between animal and fungi biomass and an absence of correlation between biomass of any group of organisms and dead root biomass.

It is possibly connected with distribution of biomass of some animal groups along the biome gradient. “Ecosystem engineers” as earthworms dominated in forest and steppe biomes not in tundra, semi-desert and desert biomes. Their biomass not correlates with total microbial biomass but with bacterial one ($r=0.65$). The significant correlation is found also for bacterial biomass and biomass of myriapods, beetles and spiders. Fungi biomass correlates with mite, spider and ant biomass while there is no correlation between springtail and fungi biomass and bacterial and Protozoa biomass.

The comparison of biomass of different trophic groups shows similar changes along the biome gradient for predator biomass and biomass of any food sources excluding dead roots. Correlation coefficient between predator and non-predator animal biomass is significant also ($r=0.71$). Nor saprovores nor bacterivore biomass shows any correlation with microbial or litter biomass.

If compare protein sources in biomass along biome gradient it is noted that significance of litter and dead roots as food sources is low although there is no obvious relation between protein volume in animal food and animal biomass. Only predators and microphytivores show significant correlation between protein sources in food and protein accumulation in biomass. It confirms by correlation coefficients between protein volume in animals and food.

The absence of correlation between bacterial biomass or protein volume in it and bacterivore biomass (protein volume) is possibly an artifact of methods of determination bacterial and bacterivore biomass (firstly Protozoa biomass).

The presence of correlation between protein volume in predator biomass and total protein volume in food webs is connected with functioning of a detritial food web in which predators are an integral character of the web resources like a “mirror” of total food resources in the web.

“Ecosystem engineers” possibly depends on bacterial sources of nutrients.

This analysis of literature data confirms the necessity of biomass and protein research for understanding of mechanisms of functioning of the web.

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Interactions between ants and spiders and phytophagous arthropods: Competition and predation on different trophic levels

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Ant colonies have great impact on the soil and the organisms inhabiting it, but they do also affect aboveground populations of different trophic levels including plants, through direct and indirect effects. Most ant species are primarily predators, but they also ingest nutrients from plants by trophobiosis with phloem-feeding insects.

Ants and spiders were studied for inter-group interactions and for effects on the remaining arthropod fauna in dry grassland on limestone.

20 field enclosures were established as experimental areas to assess the effects of top-down and intraguild predation in a two-factorial design. Either the densities of ants or of spiders or of both taxa were experimentally reduced. In control enclosures the densities of both taxa remained unmodified.

The epigeic and hypergeic fauna was sampled on three occasions during summer 2002 using a D-vac-sampler or by heat extraction from soil cores.

A comparison of enclosures with and without ants demonstrated that ants had a negative effect on spiders, especially web-building populations. Obviously, web-inhabiting individuals are more prone to attacks by ants being active in the vegetation layer or in the litter of the ground zone.

From preliminary results it appeared that ants have a measurable influence on the food web of the grassland. In addition to their role as soil engineers they are a key group in the aboveground arthropod trophic web.

Fatty acids as biomarkers for trophic interactions in soil food webs

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Animal diets are usually verified by analysis of gut contents and faeces or by foraging observations. However, the use of these methods is particularly limited in belowground systems, due to the small size of the fauna and their cryptic habitat. Assigned feeding guilds in soil environments therefore often reflect more taxonomic, rather than functional, relationships. The study investigates the use of fatty acids as biomarker for feeding strategies in soil food webs. Trophic interactions between fungi, micro- and mesofauna in microcosm experiments were studied by analysis of lipid profiles. The trophic shift of fatty acids was assessed in different food chains, which constituted of either two (fungi - grazers) or three (fungi – nematodes – collembola) levels. Comparison to lipid patterns of field populations of collembola were performed.

Analysis of the lipid composition revealed phospholipids to be generally unaffected and neutral lipids closely related to the fatty acid pattern of the food source. Neutral lipids, i.e. storage fat of animals, showed corresponding frequencies of fatty acids in host and consumer profiles. Additionally, several fatty acids were only detected in the grazer when present in the food source. The assimilation of dietary fatty acids resulted in a more diverse neutral lipid profile along the food chain. The trophic transfer of fatty acids was most obvious for monoenoic C18 and C20 fatty acids, in particular for oleic acid, which showed a shift over three trophic levels, from fungi to nematodes to collembola. The results indicate that fatty acids have potential as a tool for bioindication of feeding strategies in belowground systems. There is evidence that (i) dietary routing of fatty acids occurs into the neutral lipid fraction; (ii) animals higher in the food chain contain more individual fatty acids in comparison to animals lower in the food chain; (iii) primary consumers have no or only trace amounts of monoenoic C 18 and C 20 acids in their neutral lipid profile, whereas consumers feeding on eukaryote diet show a considerably higher frequency.

**The interaction between Collembola and ectomycorrhizal fungi,
Tricholoma matsutake; all fungal species is not always
available food resource for Collembola**

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We examined the abundance, population structure, and gut contents of collembolans obtained from agaric fruit bodies and the fungal mat soil colonized by *T. matsutake* and adjacent non-mat soil. We also examined the fungal mat soil and ectomycorrhizas containing the mat soil for identification. The fungal mat soil observed under fruit bodies of *T. matsutake* appeared whitish color, and contained considerable amounts of rhizomorph and fine roots. The brown forest soil (non-mat soil) more than 50 cm away from the place where the fruit bodies have occurred had few containing rhizomorph and fine root. Mycorrhizal tips on several root systems collected from the mat soil were identified as ectomycorrhiza formed by *T. matsutake* based on morphological features and electrophoresis profiles of PCR products amplified from rDNA. Thus, we concluded that the fungal mat soil consisted of colony of *T. matsutake*. The numbers of Collembola obtained from the fungal mat soil did not differ significantly from that obtained from the adjacent non-mat soil. The population structure of Collembola differed between the mat soil and non-mat soil. A seasonal change in the population structure was largely observed in the mat soil, and was hardly observed in the adjacent non-mat soil. Collembolans obtained from the mat soil mostly contained hyphal fragments of dematiaceous fungi and other basidiomycetes (hyaline, thick-walled hyphae with clamp connections) in their gut, the same as those obtained from non-mat soil. Some hypogastrurids obtained from the mat soil in autumn contained abundant spores of Boletaceae. Collembolan populations on fruit-bodies of 10 species including *T. matsutake* were mostly comprised of hypogastrurids. The fruit bodies of *T. matsutake* had the fewest hypogastrurids among the 10 fungal species. Collembolans obtained from *T. matsutake* contained spores and hyphae of the fruit-body of the fungus.

Decomposer food webs on differently managed alpine pastureland (Central Alps, Tyrol)

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On hay meadows at the timberline (1890 – 2100 m a.s.l., Stubai Valley, Tyrol) earthworms are the dominating macrofauna decomposers (32.3 g fw/m², 91 %). After abandonment the overall diversity of epigeic arthropods increases and among the decomposers millipedes and certain diptera larvae (Tipulidae, Sciaridae) gain in numbers (1.1 g, 5 %, 1.9 g, 8%, respectively). However, the biomass of earthworms decreases substantially (16.0 g, 70 %) as the mass of the retreating *Lumbricus rubellus* is only partially replaced by the invading, smaller *Dendrobaena octaedra*.

On adjacent pastures the biomass of earthworms is generally lower (16.8 g, 82 %), *Lumbricus rubellus* is likewise dominating (71 %) among lumbricids. Following cessation of grazing their biomass stays the same (15.9 g, 62 %), but other species such as *Dendrobaena octaedra*, *Octolasion lacteum* and *Allolobophora rosea* become important. Millipedes (*Cylindroiulus fulviceps*, *Enantiulus nanus*) triple their biomass (1.2 g and 3.7 g, respectively).

To understand how the dominating decomposer species of the established food webs react to the changing trophic conditions after abandonment the trophic positions of soil animals were determined using ¹⁵N stable isotope analysis.

Irrespective of the type of land use *Lumbricus rubellus*, *Dendrobaena octaedra*, *Cylindroiulus fulviceps* and *Cylindroiulus meinerti* function as primary decomposers, while *Octolasion lacteum* and *Allolobophora rosea* function as secondary decomposers. *Enantiulus nanus* serves as an intermediary between primary and secondary decomposers.

In conclusion the dominance structure of the decomposer community changes obviously, but the species themselves do not leave their positions as primary and secondary decomposers in the food web with the changing structure and quality of the litter system.

Analysis of feeding ecology of earthworms (Megascolecidae) in Japanese forests using gut content fractionation and $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ stable isotope natural abundances and some enzyme activities in their guts

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Megascolecidae earthworms are dominant in Japan forests. However a comprehensive study on feeding ecology of megascolecid earthworms has unknown. Therefore our aim was to clarify feeding ecology of megascolecid earthworms in Japan using combination with the use of gut content fractionation, natural abundances of the stable isotope pairs $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, and some enzyme activities in their guts. The surveys were taken out at three sites with different latitude in cool-temperate (TOEF: 42° 40' N, 141° 36' E), temperate (MFF: 35° 43' N, 139° 22' E) and subtropical (Yona: 26° 49' N, 128° 5' E) Japanese forests.

Their vertical distributions and the fractionations of gut content were analysed for ecological category determination. At TOEF and MFF, earthworm communities were composed of species living mainly in A₀ and topsoil layers. The gut contents of earthworm species living in the A₀ layer had more organic fractions, whereas that of earthworm species living in the soil layer had more inorganic fractions. Therefore these species were regarded as epigeic species and polyhumic-endogeic species, respectively. At Yona, *Amyntas yambaruensis* had a burrow through 20cm depth with casts and “midden” on the forest floor, and their organic and inorganic fraction ratio of gut content was intermediate between epigeic and endogeic earthworms at TOEF and MFF. Therefore *A. yambaruensis* was regarded as anecic. In addition, at Yona, there were two unidentified *Amyntas* spp.: one epigeic species in the midden of *A. yambaruensis*, and another endogeic species found in B-layer soil.

Natural abundances of the stable isotope pairs $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ were measured for these earthworms' food utilization. Enrichment in $\delta^{15}\text{N}$ from leaf litter to deeper soil layers was different between sites, however enrichment from resource to earthworms was similar at TOEF and MFF. $\delta^{15}\text{N}$ values showed epigeics < polyhumic-endogeics at TOEF and MFF, whereas at Yona, $\delta^{15}\text{N}$ values were in order of anecic < epigeic < endogeic. The $\delta^{15}\text{N}$ values thus appear to indicate functional niche of earthworm species via their resource utilization in the decomposition process from fresh litter to humus.

Finally, enzyme activities of cellulase, chitinase and protease were measured in the earthworm gut tissues and gut contents. Endogeics (polyhumic) and anecic had higher cellulase, chitinase and protease activities in the gut tissues than epigeics. Whereas, some epigeic had higher cellulase activity in the gut contents, and other epigeic had higher chitinase activity in the gut contents, than endogeic and anecic, thus a set of enzymes activities possessed by earthworms was different between gut tissues and contents. Accordingly, we conclude that epigeic earthworms utilize substrates on the earlier stage in the decomposition process such as soluble carbohydrates and amino acids, whereas endogeic earthworms utilize substrates on the later stage of decomposition process, such as mixture of cellulose, fungi and microbes

In summary, available resources to megascolecid earthworms among ecological groups were different, because different ecological group earthworms depended on the active substrates on different stage of decomposition process.

SESSION 6

*Soil Animals, Waste Treatment,
Detoxification and Bioremediation*

ORAL CONTRIBUTIONS

An industrial use of soil animals for environment: the treatment of organically polluted water by lombrifiltration

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Soil zoology contributions to the environment are mostly ecosystem assessments, e.g. measure of agricultural practises effects on soil fauna or toxicological tests. A few use soil animals as in vermicomposting or for soil fertility improvement by earthworm introduction.

The lombrifiltration has been improved at R&D scales to reduce water organic pollution (sewage, agro-industrial discharges, pig slurry, ...).

A Life-environment project of the European Union, called Recyclaqua, allows a first industrial use of earthworms in a controlled system for water treatment. It is designed to clean up in mean 300 m⁻³.day⁻¹ of sewage and to be a demonstration for Europe, especially through a computer assisted knowledge management and various communication tools.

The paper presents the design and the first industrial and environmental validation results.

Soil animals in detoxification and bioremediation, organic waste treatment and ecosystem restoration: earthworms as an example

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Earthworms are key organisms in soil ecosystems, in terms of soil structure, nutrient transformations and fertility. They have been used extensively in projects aimed at: detoxification and bioremediation of polluted sites; organic waste breakdown; ecosystem improvement and restoration; as indicators of soil quality; and as key test organisms in ecotoxicological testing. These uses will be reviewed and examples of research results given for each parameter.

A potential use of earthworms is in the **bioremediation** or **detoxification** of soils containing moderately elevated levels of chemicals, that exceed soil quality criteria, but are not toxic to the earthworms. During the processing of soil by earthworms, chemicals may be sequestered during aggregate formation, or metabolized to a less available form. Laboratory tests have shown that the dissipation rates of organic chemicals in soil are often enhanced considerably in the presence of earthworms. Additionally, earthworms can bioaccumulate chemicals such as heavy metals, polychlorinated biphenyls, and organochlorines into their tissues from the soil in which they live. When the earthworms are removed from the soil by expellents they can be collected and the contaminants in their tissues removed. Examples of such projects are discussed.

Some species of earthworms are used extensively in the **breakdown of organic wastes** to produce vermicomposts that are rich in available nutrients and plant growth regulators. These materials increase crop germination, growth, yield and can also suppress the incidence of plant pathogen and arthropod attacks significantly. Examples of all of these effects by vermicomposts will be presented.

Accelerated **ecosystem restoration** can be achieved by the inoculation of lumbricid earthworms into poor pastures, reclaimed waste disposal sites, open-cast mine sites, and reclaimed polders. Examples of such projects will be presented together with results and timescales.

In **ecotoxicology** earthworms were the first soil invertebrates for which a standard protocol for the testing of chemicals was codified. As such, earthworm toxicity testing data often form the foundation, for the development of soil quality guidelines for a wide array of industrial organic chemicals, pesticides, and heavy metals. Earthworms have been used extensively in single species ecological tests to assess the acute toxicity of soil contaminants as well as effects on earthworm reproduction, behavior and other systems. Earthworms also serve as prey for a number of animal species, resulting in their use in chemical bioaccumulation and trophic transfer studies. Many biomarkers of chemical exposure, such as the neutral red retention time assay, have also been developed using earthworms. Most recently, gene sequencing and the development of microarrays for *Lumbricus rubellus* has brought a genomics component to earthworm toxicology. Earthworms have also been used as key organisms in microcosm and terrestrial model ecosystem assays of the environmental effects of chemicals. Examples of the effects of heavy metals and fungicides in such systems will be given.

Soil factors associated with successful restoration of above ground biodiversity

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The pan-European research project TLinks (Trophic linkages between above and below-ground organisms as a key to successful restoration of biodiversity on ex-arable land across Europe) is studying schemes aiming at conserving biodiversity through the restoration of species-rich communities on ex-arable land. Successful biodiversity conservation depends on the functioning of the whole ecosystem, and the soil and its biotic complexity are usually overlooked, and not included as criteria or indicators in biodiversity restoration and conservation policies.

In a survey of 90 restoration sites in the UK, the Netherlands and Spain a number of soil factors was related to success of restoration. For each site, the success of restoration was also characterised by the abundance of dominant species, subordinate, and rare species of plants, birds, and other target organisms. Soil factors measured were: Soil physical and chemical parameters, Phospholipid Fatty Acids to determine bacteria to fungal ratios and biomass of arbuscular mycorrhizal fungi, nematode communities.

The influence of specific groups of soil organisms on aboveground biodiversity was evaluated with multivariate analysis techniques. The results show that the composition of plant communities can be equally well predicted by soil organisms as well as soil physical factors. Microbial communities could be analysed on a high resolution with fatty acid signatures and that degree of success of restoration could be compared to the microbial community composition. The strength of relationship between measures of success of restoration (e.g. local plant species diversity) and different soil parameters will be discussed.

Important soil factors will be suggested for use as indicators of restoration success of above-ground communities.

See <http://www.bf.jcu.cz> for more information about the project

Development of an international test guideline for the soil mite *Hypoaspis aculeifer*

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Testing effects of plant protection products on soil mites may be relevant for the listing of an active substance in Annex I of EU-Directive 91/414/EEC. There are special requirements for soil mite testing for persistent substances (EU terrestrial guidance document, chapter 6.1, “soil organisms”), and for routine regulatory testing of non-target arthropods (EU terrestrial guidance document, chapter 5.3 “non-target arthropods”) (EU 2002).

An informal expert group has started activities in the beginning of the year 2003 to view existing test approaches and discuss the state of the art. The aim of this group is to develop a harmonized test guideline which is suitable for routine regulatory testing of persistent substances and in the area of soil inhabiting non-target arthropods. The group also intends to organize an international ring test and to draft a guideline according to OECD format as soon as a suitable method has been achieved.

According to the present knowledge the soil mite *Hypoaspis aculeifer* is considered to be the most suitable test species, exposed to the test substance in soil. Currently open questions include the age of the test organisms at the beginning of the test, the most efficient extraction method and the duration of the test. The state of the art of the discussions and activities of the informal expert group will be presented.

Adaptation of the enchytraeid toxicity test for use with natural soil types

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The enchytraeid toxicity test has gained wide acceptance by soil ecotoxicologists since the release of draft document No. ISO/16387 (Soil quality — Effects of pollutants on Enchytraeidae (*Enchytraeus* sp.) — Determination of effects on reproduction and survival) by the International Standardization Organization in 2001. The ISO Guideline was developed for ecologically relevant soil annelids of the genus *Enchytraeus* and was originally intended for use with OECD artificial soil (U.S. EPA Standard Artificial Soil). The key test parameters, including duration, soil conditions (pH, moisture), and validity criteria were optimized for use with the recommended test species, *Enchytraeus albidus* Hence 1837 (white potworm; Enchytraeidae, Oligochaeta). Other species of the genus *Enchytraeus*, including *E. buchholzi* Vejdovsky 1879, *E. crypticus* Westheide & Graefe 1992 and *E. luxuriosus* Schmelz and Collado 1999, were recommended as alternative test organisms provided that the rationale for the selection of the species was clearly identified. Recently, regulating agencies in North America and European Union emphasized the importance of assessing chemical toxicity in natural soil types that support a higher bioavailability of test chemicals compared with tests conducted with artificial soil. This is necessary for developing ecotoxicological benchmark values that can be used for the derivation of conservative soil screening levels that are more protective of terrestrial ecosystems at contaminated sites.

In this contribution, results of tests performed with three different species of the genus *Enchytraeus* (*E. albidus*, *E. crypticus*, *E. luxuriosus*) and more than a dozen field soils covering a wide range of European and North American soil properties (e.g., soil texture, pH, organic matter content) are reported. From North America, these soils included Teller sandy loam (TSL), Sassafras sandy loam (SSL), Richfield clay loam (RCL), Kirkland clay loam (KCL), and Webster clay loam (WCL). From Europe, agricultural and forest soils from Germany and Portugal were sampled, each of them being similar to one of the six EURO-Soil types. In a first step, survival and reproduction of the three enchytraeid species were assessed in the various soils, while in the second step, several metals, as well as different organic compounds including pesticides, were tested in the same soils.

Results of our studies using *E. albidus* showed that this species required soils containing a relatively high organic matter content and a soil pH of about 6 (± 0.5) for optimal test conditions. In contrast, the performance of *E. crypticus* met or exceeded all ISO validity criteria in soils with a wide range of physical and chemical properties (pH – 4.0-7.4; organic matter – 1.3-3.5 %; clay content – 13-35 %). Test results with *E. luxuriosus* indicated that the requirements of this species were intermediate to those of the other two enchytraeids. These experiences show that the ISO Enchytraeid Reproduction Test can be successfully used for testing chemicals in a wide range of natural soils by selecting appropriate test species and adjusting test conditions.

Soil microstructure development during succession on chemical factory heaps

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Soil microstructure development during primary succession was studied on deposits of a former chemical factory producing nitric, sulphuric, and muriatic acids and soda at Petrovice u Karviné, NE Moravia, Czech Republic. The deposits were 10, 15, 25, 38, 48, 60 and 83 years old at the dates of soil sampling for microstructure studies in 1979 and 2002. Soil thin sections were produced from soil blocks embedded in polyester resin CHS104 and CHS109 after about 30 days lasting slow polymerisation. An open moss and lichen community with a 5 - 10 mm thick humus layer was developed at the 10 years old succession stage, the 15 years old stage had an open plant community with *Poa pratensis* and *Holcus molis* tufts and a up to 2cm thick humus layer. The forest community *Tilio-Carpinetum* in different stages of succession was developing since the 25 years old succession stage, but the understory plants were not yet rich in species even in the 83 years old stage. The raw humus was developing from the early succession stages up to the 25 years old forest, but it was a transition to a moder humus form in the upper part of the humus horizon. Moder humus was established at in the upper 5 cm of the 60 years old stage where the black to grey coloured lower part up to 10-15cm was a transition to the raw humus and to the white deposit substrate. The old stage with not yet well-developed *Tilio-Carpinetum* forest has the most developed moder humus form with well-diversified microstructure. Microarthropods, enchytraeids, dipteran larvae, diplopods, Oniscidea and epigeic earthworms play an important role in the organic microstructure formation in this most advanced succession stage. Endogaeic and anecic earthworms have not yet entered the succession. The raw humus development was characterised by a dominant activity of soil fungi and a low microstructure forming activity of soil animals. The particles of black coloured raw humus are being incorporated into the moder humus microstructures formed by the activity of the above mentioned soil animals in the most advanced succession stages. The mull humus form, typical for the climax *Tilio-Carpinetum* forests with cambisol on loess in this part of Moravia, did not developed on the chemical factory deposit substrates even after 83 years of primary succession.

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Accumulation of heavy metals by enchytraeids and earthworms in a floodplain

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The river floodplain Afferdense- and Deestsche Waarden (ADW) in The Netherlands is diffusely contaminated with several contaminants, notably heavy metals. It is, however, unclear whether this mixed contamination sorts any adverse ecotoxicological effects. The organisms studied (enchytraeids and earthworms) were exposed to contaminants in various ways, namely directly through contamination of pore water, contamination bound to solids and/or indirectly through contamination of their food source.

In November 2000 and May 2001 a field survey has been conducted in two areas in the ADW (“Rijswaard” and “Deel3”) to collect a wide range of data concerning contamination levels, bioavailability, population dynamics of enchytraeids and earthworms and abiotic factors such as % lutum, % organic matter and soil nutrient concentrations. Samples were taken along transects for soil chemical analysis and for enchytraeids and earthworms. Samples for chemical analysis were taken for 3 depths: 0-10, 10-20 en 20-30 cm. Samples for soil fauna were taken using appropriate depth increments. Earthworms and enchytraeids were analysed for heavy metal content. At both sites arsenic and zinc were present in soil at relatively high concentrations (above the Dutch intervention value). Highest concentrations were found in the 20-30 cm layer in the Rijswaard, and in the 10-20 cm layer in Deel3. The Rijswaard is flooded more frequently and has a coarser textured sediment than Deel3. This explains the fact that the pollution in the Rijswaard is found at a greater depth compared to Deel3. Cadmium, copper, chromium and nickel were present in concentrations above the Dutch target values at both sites. Both enchytraeids and earthworms accumulated metals in the two areas. Bioaccumulation factors varied for different earthworm and enchytraeid species and differed by sampling date. For instance, *Fridericia ulrikae* and *Henlea perpusilla* specimens had accumulated more cadmium than *E. buchholzi* specimens. Specimens of the earthworm species *Aporrectodea caliginosa*, *Allolobophora chlorotica* and *Lumbricus rubellus* had accumulated larger concentrations of cadmium in November 2000 than in May 2001. Population dynamics after flooding, dietary differences and/or behavioural differences in soil may have contributed to these differences. In our presentation, we will focus on different factors that may affect the accumulation of heavy metals by enchytraeids and earthworms in the two areas. Using multivariate regression analysis we will express bioaccumulation by earthworms and enchytraeids as a function of environmental variables that control the distribution of heavy metals over the solid and liquid phases. Dominant primary factors are soil acidity, organic matter content, clay content and contaminant concentrations.

SESSION 6

Soil Animals, Waste Treatment, Detoxification and Bioremediation

POSTER CONTRIBUTIONS

Herbicide sorption with soil components as affected by the soil macrofauna

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Without doubt soil biotic interactions have also to be considered to adequately assess herbicide sorption and availability in soil, however little research have been undertaken to assess the role of soil fauna in these processes. Regarding the soil fauna, earthworms greatly disturb the soil structure and soil porosity by their casting and burrowing activities, leading to significant changes in physico-chemical and microbial soil properties. Earthworms ingest preferentially the finest mineral soil particles (mostly clays) and the organic ones (leaf and root litter debris, fungal and bacterial cells). As a result, casts often have much higher contents of OM and nutrients and contain more fine-textured material than the surrounding soil. In addition, some polysaccharides (intestinal mucous) are excreted and mixed with soil during gut transit. Therefore, earthworm casts seem particular the soil structure wherein the adsorption of the molecules and their bounding with the soil matrix might be different than in un-ingested soil. Recently it was shown that atrazine was more strongly retained on casts than on soils and that earthworms increase the non-extractable herbicides fraction in soils.

The present studies aims to assess by which mechanisms earthworms lead to higher atrazine sorption thus reducing its availability in soils. AT sorption by surface and subsurface horizons of two hydromorphous coarse-textured soils were studied and discussed in the connection with soil properties, especially regarding composition of humic substances, and mineralogical composition of bulk soil samples and their clay fractions. The two soils were sampled from a natural riparian wetland located along a 4th order stream at 10 km south-west of the Mont Saint-Michel Bay (Brittany, France). Special attention has been paid to modifications of atrazine interactions with soil components due to the influence of earthworms on soil properties by soil ingestion.

Use of earthworms for recycling fly ash as a source of plant nutrients

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Large scale generation of fly ash from different coal fired plants is now emerging as a major environmental threat due to problems associated with its bulk disposal. Various technologies for disposal and re-use of fly ash are being adopted in different countries of which application of fly ash for agricultural cultivation forms an important component. Because availability of many nutrients is very low in fly ash, despite their high occurrences in total amount, available ranges of such nutrients need to be improved to increase the acceptability of fly ash as a source of plant nutrients. In the present study, attempts were made to introduce epigeic species of earthworm *Eisenia foetida* to different combinations of fly ash and organic wastes to increase the microbiological activities on fly ash and to improve, thereby, the availability of different nutrients in fly ash. The results revealed the earthworm acted mixtures of fly ash and organic wastes to exhibit considerably higher availability of different plant nutrients viz. N, P, K, Fe, Cu, Mn and Zn . It was calculated that significant contributions of most of such increments came from solubility of fly ash.

Impact of alternative technologies to the use of methyl bromide on root-knot nematodes and soil free-living nematode populations dynamics

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Four alternative technologies to the use of methyl bromide (MB) in soil fumigation — resistant rootstock, metham sodium (MS), dosage reduction of MB and MS by virtually impermeable films (VIF) cover, soil solarization combined with selected biological control agents (SS+BCA) — were chosen for application to an experimental site in Qingzhou (Shandong Province, China) from Jul.2002 to Jul.2003. The treatments were: SS+BCA, MB, MB+VIF, MS and MS+VIF. Two tomato (*Lycopersicon esculentum* Mill) cultivars, cv. Maofen-802 from the Xian Institute of Vegetables China and cv. resistant rootstock (beaufort SIS-1 *Lycopersicon lycopersicum* × *L. hirsutum*) from Italy (Nuovo Centro s.E.I.A. SpA), were selected as test crops. Maofen-802 as scion was grafted with beaufort. In each plot, Maofen and grafted maofen tomato were planted half to half. The total number of root-knot nematodes (*Meloidogyne incognita*.) and galling index, the free-living nematode populations were investigated respectively. The results are as follows:

1. Nematodes were identified mainly into five ~~Rhabditida~~ Rhabditida, Tylenchida, Dorylaimida, Tylenchida, Monhysterida. Furthermore they were distinguished into four trophic groups: bacterivores, fungivores plant parasites, omnivores/predators based on the genus level.

2. The density of second stage juvenile of root-knot nematodes reached the highest level in May and June 2003. The result of surveying the galling index show that the resistant rootstock can effectively control the root-knot nematodes, the average galling index was 45.6 in Maofen and 4.5 in grafted Maofen. Chemical soil fumigation practice also decreased obviously the root galling index, however, the efficiency was not as high as resistant rootstock. The root galling index of SS+BCA plot was the highest of all five treatments and reach 65.8 (in maofen) and 7.1 (in grafted maofen). The density of J2 was in inverse proportion to some beneficial free-living nematodes such as Rhabditida, Tylenchida, Dorylaimida. The correlation coefficient of nematode proportion between J2 and Rhabditida, Tylenchida, Dorylaimida nematodes were -0.87, -0.52, -0.61, respectively in Maofen soil, and -0.79, -0.56, -0.61 respectively in grafted maofen soil.

3. The resistant rootstock can decrease the density of fungivorous and plant parasitic nematode populations. Soil fumigation can decrease the density of plant parasitic nematode populations. For the total number of plant parasitic nematodes in treatments, there was not significant difference among the four chemical fumigations but significantly lower than in SS+BCA treatment.

4. The resistant rootstock can decrease the PPI/MI (plant parasite index/maturity index) value of nematodes community, which present no significant difference among the five soil fumigation treatments.

Key words: root-knot nematode, free-living nematode, methyl bromide, soil fumigation

Effect of chemical soil disinfection on protozoa abundance and community structure in tomato greenhouses

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This study was designed to understand the impact of methyl bromide (MB) (CH₃Br) and its alternatives on the abundance of soil protozoa. A randomized complete block experiment with five treatments and 4 replicates (each replicate in a separate greenhouse) was established in Qingzhou, Shandong Province, China. In addition to MB and untreated control (CK) treatments there were three alternative soil fumigation practices including MB+VIF (virtually impermeable films), metham sodium (MS), and MS+VIF. Tomato (*Lycopersicon esculentum* Mill) cultivars, cv. Maofen-802 from the Xian Institute of Vegetables (China) was selected as test crops.

The research demonstrate the effect of these four soil fumigations on soil protozoa through a three-level ten-fold dilution method. Soil fumigation was carried out in July 2002. The abundance of three groups of soil protozoa-flagellates, amoeba and ciliate were measured from July 2002 to May 2003, with soil samplings taken in eight times during this period. The results indicate that the four chemical soil fumigations significantly repressed the reproduction of soil protozoa in the process of reducing soil diseases and pests. The effect of methyl bromide on flagellates was higher than that for metham-sodium, while the two treatments with VIF film greatly strengthened the repression effect on flagellates. Flagellate abundance was also influenced by the growth state of the tomato, while ciliate and amoeba were influenced primarily by the soil fumigations. Methyl bromide had a stronger and longer affect on amoeba than did metham-sodium.

Key words: fumigation; soil protozoa; abundance; community structure

Succession of nematodes in ash dumps reclaimed by covering with turf

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The study was carried on ash dumps being a by-product of the combustion of hard coal in the power plant "Siekierki" in Warsaw vicinity. Ash dumps were reclaimed by using one of the methods applied for prompt transformation of industrial wastes into a biological environment; the ash dumps were covered with turf coming from the bank of Vistula (with mineral soil – light loam warp soil) or from the of Biebrza River valley (with organogenic soil –adler peat). Soil samples were taken from ash dump which at the beginning of the study has been reclaimed for 2 years and covered with i) turf on mineral soil, ii) turf on organogenic soil, and iii) ash dump which has been reclaimed for 8 year and covered with turf on organogenic soil. On every ash dump sampling was made during three years, twice per year: in the spring and in the autumn.

The aim of the study was analysis of changes in nematode communities in succeeding years of reclamation with turf on mineral or organogenic soil.

Nematodes extracted by modified Baermann method were counted and identified to genus level. In both ash dumps reclaimed shorter bacterial feeding general opportunists dominated, followed by fungal feeding general opportunists. *Acrobeloides* dominated in bacterial feeding group achieving in some samples more than 50% of the total community, while *Aphelenchus* followed by *Aphelenchoides* dominated as fungal feeding nematodes. In the ash dump reclaimed longer bacterial and fungal feeding species were less abundant than in the dumps reclaimed shorter. In this dump plant feeding species increased achieving in some samples more than 30% of the total community.

The results of Canonical Correspondance Analysis (CCA) indicated that the first canonical axis separated sites reclaimed longer from those reclaimed shorter. Many genera of nematodes were not affected by time of reclamation, however *Malenchus*, *Mesorhabditis*, *Rotylenchus*, *Protorhabditis*, *Labronema* and *Carcharolaimus* were more common in the ash dump reclaimed longer than in ash dumps reclaimed shorter.

The composition of nematode community was more affected by the time of reclamation than by the kind of soil used for covering the ash dumps.

The fate of human pathogens during vermicomposting

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Sewage biosolids and many animal wastes contain human pathogens such as *Salmonella spp.*, human coliform bacteria like *Escherichia coli*, enteric viruses and helminth ova. In USA, the Environmental Protection Agency (EPA), imposes severe restrictions on the disposal of sewage biosolids on agricultural land, unless populations of human pathogens have been reduced to scheduled low levels termed Class A. Such low pathogen populations can be achieved through traditional thermophilic composting for 72 hours at temperatures above 55° C with regular stirring.

By comparison, vermicomposting is a mesophilic, organic waste degradation process, using species of earthworms such as *Eisenia fetida* to oxidize, humify and stabilize organic wastes, and convert the nutrients they contain into plant-available forms. Work in our laboratory has shown that vermicomposts increase plant germination, growth, flowering and yields significantly.

This paper will review a number of laboratory and field experiments which have studied the reduction of human pathogens using several methods of vermicomposting. Data will be presented from three experiments documenting significant reductions in human pathogens during vermicomposting.

In a laboratory experiment, small plastic boxes (20 cm x 10 cm x 10 cm deep) were used to study reductions in populations of *E. coli* and *Salmonella spp.* with all treatments replicated four times. The treatments were:

(i) Sewage biosolids, inoculated with pathogens, with or without 100 g. of *E. fetida* per box, (ii) Biosolids, uninoculated with pathogens, with 100 g. earthworms or without earthworms per box, (iii) Cattle manure, inoculated with pathogens, with 100 g. earthworms or without earthworms per box, (iv) Cattle solids, uninoculated with pathogens, with 100 g. earthworms or without earthworms. The pathogens (both inoculated and uninoculated) were reduced to EPA acceptable levels in 50-70 days and there were few reductions in pathogen levels without earthworms.

In an experiment using larger boxes, (1 m x 2 m x 1 m deep), three boxes containing biosolids were inoculated with *E. fetida* and three left with no earthworms. In the boxes with earthworms the pathogens, *Salmonella sp.*, *E. coli*, enteric viruses and helminth ova were reduced to EPA acceptable levels in 50 days.

In an outdoor windrow experiment three windrows of sewage biosolids contained large populations of *E. fetida* and three had no earthworms. All windrows were inoculated with high levels of *E. coli*, *Salmonella sp.*, enteric viruses and helminth ova. All the human pathogens were reduced to levels acceptable to the EPA for land use over 7 days.

Clearly, vermicomposting provides an effective method of reducing human pathogens, probably by destruction of pathogens in the earthworm gut.

Evaluation of metal pollution of the grounds of the borders of the Rhumel Wadi by earthworms

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Our study was carried out on the soils of the edges of the Rhumel wadi in the area of Constantine (East Algerian) on five station and 45 points of sampling. The soils physicochemical analyses revealed a homogeneity of the area of study with muddy soils and sandy silt. The soils contents of these heavy metal are on average: 5,58 ppm Cd ; 131,56 ppm Cu ; 112,12 ppm Pb and 51,78 ppm Zn.

The taxonomic study of the earthworms taken in the area of study revealed the presence of five kinds, with 10 species: *Heraclescolex*, *Nicodrilus*, *Octodrilus*, *Koionodrilus* and *Eisenia*. This settlement presented an average abundance of 32,56 worms/m² and an average biomass of 286,39 g/m². Their contents of these four metals are on average: 17,05 ppm Cd ; 71,98 ppm Cu ; 100,56 ppm Pb and 272,28 ppm Zn.

The metal contents of the two compartments present significant variations according to the various studied stations and kinds of earthworms. The ratio of accumulation of these metals is on average: 4,72 ; 0,67 ; 0,86 and 6,59 respectively for Cd, Cu, Pb and Zn.

Thus, the earthworms of the studied area accumulate these metals according to the following sequence (Zn > Cd > Pb > Cu). This taking away would depend on the physicochemical factors of the soils, the content of these heavy metals and also of the species of earthworms.

The use of the earthworms for the evaluation of the soils contamination by these four heavy metals is recommended since their body concentrations increase in a progressive way with the soils contents of these metals.

Key words: Earthworms, soil, heavy metal, cadmium, copper, lead, zinc, contamination, accumulation, bioindicator.

Roles of earthworms in elimination of highly compacted zones in field conditions

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Earthworms as ecosystem engineers influenced a great number of physical, chemical and biological processes in soil. It is often claimed that earthworms can have a great influence on the elimination of compacted zones in the soil. We wanted to put this assumption to the test. A field experiment was initiated in 1989 in northern France to evaluate the effects of cropping systems on the structure of the tilled layer in a loamy soil. Three levels of compaction were considered depending on the rotation and on the time of field operations because of high axle loads. Tillage (and no-tillage) was considered as a second factor. Earthworm populations were sampled in the different systems. If densities were high (between 100 and 400 ind./m²), only four earthworm species were found (*L. terrestris*, *N. giardi*, *A. rosea* and *A. caliginosa*). Tillage had a clear negative effect on earthworm density (especially on *A. rosea* and *N. giardi* which seemed to be more sensitive). The level of compaction had a negative effect too on earthworm density (and *A. caliginosa* was almost absent from the most compacted soils). To determine if the remaining worms could decrease the importance of compacted zones, observations were made on horizontal planes (3 m length and 1 m depth). Compacted zones were counted and presence of earthworm macropores inside the compacted zones were noted. We observed that the presence of macropores in compacted soil was significantly higher in no-till treatment. Moreover, the number of compacted zones decrease with time, this could be due to an "earthworm effect". To go further, soil cores (diameter = 16 cm and length = 40 cm) were sampled in the most compacted zones. Using X-ray tomography and image analysis, we were able to show that earthworm macropores were still present in great number.

The effect of Bt-corn on decomposers and decomposition rates of corn post-harvest residues under laboratory and field conditions

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Effects of Bt corn on the decomposition of corn post-harvest residues, abundance of dominant groups of soil fauna, microbial biomass, microbial respiration and composition of the microbial community assessed by phospholipid fatty acid analysis (PLFA) were studied in two field experiments in the Czech Republic (near Prague and Brno). At each experiment location, Bt corn and the same cultivar of non-Bt corn were each planted on half of the field as monocultures, and repeated at both location for three years. Field microcosms containing litter bags of Bt or non-Bt corn post harvest residues and matching field soils were exposed in matching field plots for 2 years as completely randomized blocks. Microcosms were sampled 5 times during exposure. On each occasion, the decomposition of litter bag contents, abundance of soil fauna in whole microcosms, and the microbial properties of mineral soil in close vicinity of the litter bags were determined. No significant effects of Bt corn on investigated parameters were recorded in either location evaluated separately or for combined data. However, several parameters, such as microbial biomass and community analysis using PFLA indicated significant differences between the same treatment in both experimental locations (Prague and Brno).

Either fresh post-harvest residues or post-harvest residues exposed in soil for 60 days from the above fields were used to study the effect of Bt corn on microbial respiration and population growth of *Enchytraeus crypticus* (Oligochaeta: Enchytraeidae) in laboratory tests. Significant (about 30%) reductions of *E. crypticus* population growth on fresh Bt corn litter in comparison with non Bt corn was observed. However, this was not observed in litter exposed in soil for 60 days.

In conclusion, Bt corn may have a deleterious effect on decomposers in the laboratory, but these effects were minor and restricted to the initial stages of decomposition and undetectable in long-term field experiments.

How do enchytraeid populations survive in heavy metal contaminated environment?

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We have studied how long-term heavy metal exposure has affected distribution, life history patterns, population dynamics, metal avoidance behaviour and genetic diversity of the enchytraeid *Cognettia sphagnetorum* in northern coniferous forest soil. In our study area around a Cu-Ni smelter in SW Finland *C. sphagnetorum* is very abundant comprising more than 95% of the enchytraeid fauna. The only observed mode of reproduction of this species in the area is asexual fragmentation and regeneration. Enchytraeids have been sampled for many years along the heavy metal contamination gradient from the smelter. Individuals have also been taken to the laboratory for microcosm experiments and to examine life history properties and variation at allozyme loci (using cellulose acetate gel electrophoresis). Two main sources of enchytraeids for these studies have been a contaminated site 2 km and an uncontaminated control site 8 km from the smelter. *C. sphagnetorum* clearly suffers from the metal contamination close to the emission source population density being significantly lowered at the 2-km site and enchytraeids practically lacking from closer than 1 km from the smelter. Population densities, however, have appeared to be highly varying from season to season and from year to year. In the contaminated area, metals were heterogeneous distributed in the soil. Distribution of enchytraeids was, however, even more heterogeneous. Surprisingly, soil metal concentrations did not significantly correlate negatively with enchytraeid numbers (both metals and enchytraeids were analysed from the very same samples with an area of 25 cm²). Individuals from the contaminated site (2 km from the smelter) had lower growth rate, reproduced at a smaller size and produced juveniles of larger size than individuals from the uncontaminated site (8 km). These differences seemed to disappear, however, after one or two generations in the laboratory. Enchytraeids sampled from the contaminated site had somewhat increased resistance to Cu and they avoided Cu-contaminated soil more sensitively than enchytraeids from the uncontaminated site. *C. sphagnetorum* from the uncontaminated site had consistently higher population growth rate, both in uncontaminated and Cu contaminated soil. Generally, for both populations, growth rate was significantly lower in contaminated soil. No differences in decomposition activity (measured as CO₂ production) between the soils with the different *C. sphagnetorum* populations were found. Most alleles appeared to be shared in both populations, but there were more unique alleles in the population living at the uncontaminated site. Thus, enchytraeids with exposure history seem to have less variation at allozyme loci than those living at uncontaminated site. Because enchytraeids are important in decomposition processes and because only one species is usually dominating in enchytraeid communities in boreal coniferous forest soils, they seem to offer a proper and relevant tool for monitoring of contaminated field soils.

Soil invertebrates in prospective ecotoxicology

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Impacts of heavy metals on soil organisms and ecological functions in a retarding basin, Japan

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It recently is recognized that there is a need for estimating the impact of soil pollution on ecosystems, including soil organisms. In Japan, however, much attention is paid to human health in soil quality guidelines, and studies of the effect on soil ecosystems are lacking. The aim of this study is to estimate the effect of heavy metals on soil ecosystem at the metal-polluted field, and we made system level analysis with a battery observation of soil microbes, soil fauna and plants. The study sites were in a retarding basin dominated by tall grasses (*Phragmites communis* and *Miscanthus sacchariflorus*). The heavy metal pollution was caused by the mining activity at the headwaters since 1878 to 1960s. We set up two sites (polluted and reference) in the grassland, and compared physical and chemical properties of soils, macrofauna and mesofauna sampling, and BiOLOG tests for estimating bacterial community structure. To detect the effect of pollutants on ecological functions, we also estimated the plant biomass and the cellulose decomposition rates.

The total concentrations of heavy metals in HNO₃ extractions, especially copper, zinc and lead, were much higher at polluted site (249, 199 and 74 mg/kg, respectively) than reference site (29, 69 and 28 mg/kg, respectively), however the available concentrations in CaCl₂ extractions were both very low level (<0.5mg/kg). This suggests that geophagous species (e.g. earthworm) might be more affected than other feeding mode species. The numbers of macrofauna were different between the study sites. Notably large size animals, such as millipedes and earthworms, were more abundant in the reference site, while the centipedes and dipteran larvae were in greater numbers in the polluted site. The result of BiOLOG test showed the differences of bacterial functional communities in each site, and bacterial community in the polluted site would have increased the average resistance to a stress factor due to pollution-induced community tolerance. The shoot biomass of *M. sacchariflorus* in the reference site was higher than the polluted site. The decomposition rates of cellulose were faster in the reference than the polluted site.

These results showed that the heavy metal pollution changed the composition and abundance of macrofauna, also bacterial community, and decreased the ecosystem function (plant biomass and decomposition rate). The heavy metal impact was detected in the whole trophic levels.

Effect of ivermectin residues on earthworm activity, Megascolecidae and pat disappearance in grassland

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Anthelmintics such as an ivermectin are excreted in the feces of livestock as a mixture of parent and metabolites compound. Thus, the uses of anthelmintics in farming cause a negative impact on non-target invertebrates, such as dung beetles and earthworms, which feed on dung and contribute to pat degradation in grassland ecosystems. A delay of a dung decomposition rate leads to fouling a pasture and restricting nutrient cycling. In order to detect the effects of ivermectin on earthworm, some studies conducted in Europe, but not conducted in Japan where Megascolecidae is a dominant earthworm. This study examined the impact of ivermectin in the dung made by artificially adding ivermectin on earthworm activity and the disappearance of dung in grassland.

The experiment was carried out between 15 October and 3 December 2003 in grassland located in Fukushima City (37°43' N and 140°23' E), Japan. Spiked dung, 0, 0.1, and 1 mg ivermectin kg⁻¹ dung were prepared. 0.1 mg kg⁻¹ is the average of maximum concentration excreted from cattle treated recommended pour on administration in Japan, and the maximum concentration excreted from cattle does not exceed 1 mg kg⁻¹. A dung-free treatment was prepared to determine whether earthworms were gathered round dung. Each artificial pat, 700g wet weight was placed on surface soil on 15th October. All treatment dungs including dung-free were evenly spaced at 1.5 m intervals in an alternating sequence across the field. Pats were collected in 1, 3, 5, 7 weeks after setting pats in four replications. Remaining pat weight was measured. Each treatment comprised sixteen pats. Earthworms were collected from 25×25 cm squares underneath and around pat at depth of 0 to 5 cm and 5 to 10 cm. Earthworm collected were counted and weighed.

There is no significant difference between different treatments on the number of earthworm and the pat disappearance rate. The disappearance rate of 3 and 7 weeks after setting pats were 60% and 76% respectively. The earthworm number in dung treatment was about three times as many as the number in dung-free treatment. The average number of worm in dung treatment was 31.7 in 25×25cm areas. The weight of worm was increased with time in dung treatment, but the trend was not shown in dung-free treatment. In this field Megascolecidae was occupied more than 90% and 99% in individual and wet weight respectively. *Amyntas heteropodus* and *Amyntas divergens* were dominant earthworm. In this field, dung beetles were rare.

Earthworm gathered round the dung regardless of ivermectin treatment and the trend continued until the end of the experiment. And also dung beetles were rare. Earthworm must have the most important role about pats disappearance in this field. Therefore we think there would be no effect of ivermectin on pats disappearance. The sampling occurred at Lumbricidae dominated site in other studies showed that ivermectin had no effect on earthworm. In the present study we showed the drug had no effect on Megascolecidae. We conclude that ivermectin does not affect on earthworm activity and pats disappearance.

Earthworm field studies within pesticide registration – experience with current guidelines

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In 1994, the German Biological Agency for Agriculture and Forestry (BBA, Braunschweig) published a standardised guideline for testing the effects of pesticides on earthworms in the field (BBA VI, 2-3). Five years later, this guideline was (nearly completely) taken over by the International Organisation for Standardisation (ISO 11268-3). Thus, experiences have been gained with this method now for about 10 years in the area of pesticide registration. It is still the only ecotoxicological field test method standardised so far. The methods used to sample earthworms described in the two guidelines have recently been re-formulated in order to monitor earthworms for the assessment of biological soil quality in general.

In 2002, an expert group met in Braunschweig in order to summarise the experiences on field studies with pesticides and to discuss possible improvements. The discussion was based on a compilation of results provided by contract laboratories and laboratories from chemical industry. The main recommendations and open questions summarised at that meeting will be presented. The participants agreed that in general the guideline is well structured and does not contain major drawbacks.

However, several issues need further discussion in detail: For example, the minimum number of worms at arable test sites (20 ind/m²) as given in the guidelines is often not sufficient for statistical analysis, but it is difficult to define a higher number which is still realistic for European agricultural soils. In addition, while such a field test should be performed as closely as possible to realistic GAP (Good Agricultural Practice), it must be assured that the earthworm population is not harmed by ploughing or e.g. the use of herbicides.

On the technical level, the possibilities to exchange the expellent formalin by another, potentially less toxic compound has been intensively discussed. For example, mustard was proposed as such an alternative. However, the experiences presented do not support such an exchange due to the low efficiency of these expellents.

The evaluation of results was most intensively discussed, i.e. how can an effect be defined as significant and relevant? Since very often the number of individuals per species is too low for the statistical evaluation, a combination of species was recommended according to life-forms (epigees, aneciques or endogeas) in addition to the assessment of the total population and the dominant species (those with more than 10% dominance or more than 10 – 15 ind/m²). More importantly, any reduction of abundance or biomass of the total population or of a dominant species by more than 50% (statistically significant or not) was considered to be a relevant. In case a reduction of 30 – 50% is observed, the reduction should be statistically significant in order to be relevant. Nevertheless, very often an “expert judgement” is needed for the assessment of such a complex field study.

Survival and behaviour of three species of earthworm in lead treated soils using the OECD acute earthworm toxicity test

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This study compares the avoidance behaviour, mortality and total Pb tissue accumulation in three ecologically different earthworm species. Mature (clitellate) *Eisenia andrei* Bouché (ultra epigeic), *Lumbricus rubellus* Hoffmeister (epigeic), and *Aporrectodea caliginosa* (Savigny) (endogeic) earthworms were placed in soils treated with Pb(NO₃)₂ to have concentrations of 1 000, 3 000, 4 000, 5 000, 7 500 and 10 000 mg Pb kg⁻¹. Earthworm mortality and weight were recorded every 7 days. LC50^{+95% confidence limit}_{-95% confidence limit} calculated after 28 days were *E. andrei* 5824⁺⁸⁹⁸₋₃₆₁ mg Pb kg⁻¹, *L. rubellus* 2867⁺¹⁴⁵₋₁₉₃ mg Pb kg⁻¹ and *A. caliginosa* 2747⁺²³⁹₋₃₀₄ mg Pb kg⁻¹. *A. caliginosa* and *L. rubellus* experienced higher mortality when exposed to Pb(NO₃)₂ than *E. andrei* at concentrations below 5 000 mg Pb kg⁻¹. All species had 100% mortality at 10 000 mg Pb kg⁻¹. EC50s for weight change calculated after 28 days were *E. andrei* 2841⁺¹⁵⁰₋₆₈ mg Pb kg⁻¹, *L. rubellus* 1303⁺²⁴⁰₋₂₀₁ mg Pb kg⁻¹ and *A. caliginosa* 1208⁺²¹²₋₂₀₆ mg Pb kg⁻¹. At any given soil Pb concentration *E. andrei*, *L. rubellus* and *A. caliginosa* all accumulated Pb in their tissues at similar concentrations over 28 days. In a soil avoidance test where soils were treated with Pb(NO₃)₂ to give concentrations ranging from 300-10 000 mg Pb kg⁻¹, *E. andrei*, *L. rubellus* and *A. caliginosa* increasingly avoided the treated soils as the concentration of Pb(NO₃)₂ increased. Generally there was no difference in avoidance behaviour, however *A. caliginosa* were the least sensitive when exposed to 600 mg Pb kg⁻¹. This study demonstrated that *E. andrei* is less sensitive than other species to Pb. These differences most likely relate to physiological adaptations associated with the modes of life of the earthworms, and could have serious implications when using earthworms as a biological monitor to assess contaminated soils and the toxicity of chemicals.

Role of earthworms in the stabilization of organic wastes: A comparative study

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The overproduction of organic wastes by industrial cattle breeding and the difficulties presented by their direct application on crops, show the necessity of transforming this material into a more stabilized one so that no damage is caused to crops and the environment in general

In this study three possible alternatives of biological stabilisation are presented and compared in order to discover the main differences between them and the features and agronomic potential of the materials resulting.

The material utilized was cow manure, which was subjected to: i) 15 days composting. ii) Vermicomposting with *Eisenia* sp. iii) Vermicomposting with previous composting.

The original material was also conserved under field conditions in order to observe its evolution without any treatment, as well as under refrigeration at 0°C to compare the features of the fresh material with stabilized ones. There were five replicates of each treatment.

These different stabilisation processes, lead to the modification of physical, biochemical and microbiological parameters, and their study could serve us as an indicator of the stability of the organic waste and show us the efficiency of the treatments.

The materials resulting from the different processes were analysed in order to describe their physical properties (moisture, pH, conductivity), to quantify the microbial activity and biomass (induced and basal respiration, microbial C and N, enzyme activities, ergosterol content, presence of pathogens), and to estimate their nutrient content and nutrient availability and their CEC.

The conclusions obtained serve not only to determine the stabilization level of each material and therefore its quality for cropping, but also to clarify the differences between composting and vermicomposting and to show the role that earthworms play in the stabilisation of organic matter and their capacity to produce good quality products.

Analyses of earthworm abundances & diversity in earthworm field studies performed for pesticide registration

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Registration of plant protection products legally requires to provide toxicity data on earthworms. In a tiered approach the acute and chronic toxicity is assessed in laboratory experiments following internationally accepted guidelines. Following risk assessment schemes (regulated by EU-directives) the no-observed-effect-concentration (NOEC) of the test substance, determined during the chronic test is compared to its predicted environmental concentration (PEC) to obtain a toxicity-to-exposure-ratio (TER). If the TER is ≥ 5 , the risk for earthworm populations in the environment is assumed to be very low. In cases where this tier 1 risk assessment leads to TER values < 5 , an earthworm-field-study is triggered.

Field studies on earthworms for European registration purposes now follow a standardised guideline (BBA VI, 2-3) first published in 1994 by the German Biological Agency for Agriculture and Forestry (BBA, Braunschweig), which was later on nearly completely adopted by the International Organisation for Standardisation (ISO 11268-3, 1999).

According to the recommendations of these guidelines several earthworm field studies have been performed in the past years in our Institute and experiences in handling these complex and expensive field studies have been gained and will be presented in terms of:

- 1) choice of the test site : The test site used for the studies is a uniform grassland area of about 0.5 ha. In special cases a part of this land has been ploughed to address the good agricultural practice (GAP) of the test item studied.
- 2) earthworm abundances and the change of abundance in the control plots during the test which is influenced by weather conditions and season .
- 3) description and efficiency of the Formaline sampling method as compared to hand sorting.
- 4) species diversity on the test area over the years, also influenced by the seasons (weather conditions).
- 5) The main characteristics of the test designs, depending on test item studied.

Responses of earthworms to heavy metal exposure – consequences in decomposition processes and metal availability

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Species- and population-specific differences in the responses of earthworms to Cu and Zn exposure were studied in microcosm experiments. Ecologically different earthworm species *Aporrectodea tuberculata*, *Lumbricus rubellus* and *Dendrobaena octaedra* were chosen for the studies, and several parameters were measured from the earthworms and the soils in the microcosms. For *A. tuberculata*, two populations with different exposure histories were compared in a similar experiment. *D. octaedra* is an epigeic species which lives mainly in the litter and humus layers feeding on decomposing litter and microbes associated with it. *L. rubellus*, while burrowing in the upper soil layers, is also an epigeic species feeding on leaf litter. *A. tuberculata* as an endogeic species burrows and feeds deeper in the soil profile. Each microcosm received homogenised forest soil and five earthworm individuals from one of the populations and species under the study. Microcosm series without earthworms were also constructed. For each population and species, microcosms containing control soil (without metal addition) and soils with two combined Cu/Zn –concentrations (79/139 and 178/311 mg kg⁻¹ in dry mass of soil, respectively) were prepared. The microcosms were destructively sampled after 14 weeks incubation in a climate chamber. In addition, microcosm series, from which soil and earthworm samples were taken at four weeks intervals, were established to determine temporal changes in the availability of metals in the soils and their accumulation into the earthworms. Survival, biomass changes and offspring production (number of cocoons and hatchlings) of the earthworms were determined for each microcosm. Protozoa parasite (gregarine sporozoan) infection level in seminal vesicles of the adult individuals was also estimated. Functional responses to the metal exposure were studied by measuring decomposition activity as CO₂ production of the microcosms (using infrared carbon analyser) and by analysing mineral nitrogen forms from the soils. Effects of the earthworms on the availability of metals in the soils were evaluated using samples taken from the microcosms at the end of the experiments. Cu and Zn were sequentially extracted from the samples to partition them into five fractions starting from an exchangeable (weak MgCl –solution) and ending in a residual fraction (strong nitric and hydrochloric acid solution). Metal concentrations of the earthworms and faeces produced to the soil surface were also measured. In addition, avoidance responses of the earthworms were determined (48 h two-section avoidance test procedure) to find out whether the earthworms are able to avoid Cu and Zn contaminated soils. All species avoided sensitively metal contaminated soil. *D. octaedra* appeared to be the most sensitive and *L. rubellus* the least sensitive species. On the other hand, no differences were found between the populations of *A. tuberculata* with different exposure background. Other analyses of the data are in progress and main results together with their interpretation will be presented in the colloquium.

Vermicomposting of industrially produced woodchips and sewage sludge utilising *Eisenia fetida*

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Adult *Eisenia fetida* were used to vermicompost of woodchips and sewage sludge that are produced as waste product by platinum mines. The aims of the study were to examine the growth and reproductive success of the worms over 84 days, to determine long-term feasibility of large-scale implementation, monitor the bioconcentration of heavy metals and the effects of micro-organisms inoculation to quantify possible environmental implications. Results revealed that there were no effects on growth ($P > 0.05$), reproductive success decreased ($P < 0.05$) and Al, Cu and Ni were bioconcentrated ($P < 0.05$) in the treatment groups without an inoculate. Earthworms in the treatment group with the micro-organism inoculate manifested no effects on growth or reproductive success and did not accumulate Al, Cu, and Ni. It is concluded that the only economically feasible way to bioconvert woodchips and sewage sludge to a potential ameliorant of platinum mine tailings would be with the addition of a micro-organism inoculate.

The Role of earthworms in radionuclide turnover

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Earthworms (Lumbricidae) are as known to be the most important group of soil animals in temperate regions of the world. Earthworms are probably the most important members of the soil biota and major contributors to total zoomass. To best understand earthworm-mediated changes in turnover knowledge on limiting elements and their modification by earthworms considered of prime importance. In this study, the effect of bioturbation by earthworms on the distribution of radionuclides investigated. The data presented here prove the substantial contribution of earthworms to litter decomposition in forest soils. The specific objectives were to examine: the effects of earthworm species on the distribution of radionuclides down the soil profile and litter.

Monthly 25x25 cm soil samples were taken during several years at 6 different sites with different levels of radioactive contamination. Earthworms were hand sorted from four successive soil layers, 10 cm in depth. The radionuclide availability was determined in the four compartment resulting from earthworms activities: casts, burrow linings, litter and soil.

Only three species of Lumbricidae were found in radiocontaminated soils: Species diversity and density were lower than those reported from control sites. Earthworms contribute to Cs¹³⁷ and Sr⁹⁰ through the accumulation (consumption), storage (assimilation) and turnover (respiration, excretion, mortality) of radionuclides from their tissues. It seems that the physico-chemical conditions of radiocontaminated soils provide an inhospitable environment for earthworms. The results showed similar correlations of the bio-concentration of radionuclides in earthworms with either the total contents of soil radionuclides or their bioavailabilities. Radionuclide accumulation in earthworm tissues increased with increasing radionuclide contamination. Radionuclide accumulation in earthworm tissues was 10 – 12 % lower in juveniles than in matured worms. Radionuclide availability in the casts correlated positively to the radionuclide contamination.

The study was designed to describe the flows of Cs¹³⁷ and Sr⁹⁰ through the three components: litter, soil and earthworms.

Thus, the contribution of Lumbricidae is a key aspect of radionuclide cycling in the environment.

Earthworm digestive motility as a new biomarker for ecotoxicological studies

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Earthworm is a relevant indicator of environmental changes and is currently used as a biomarker for assessing chemical pollution. By making burrows in the soil, it influences various soil parameters (porosity, microbial activity, aeration). Burrows are made either by inserting prostomium between aggregates and pushing soil or by ingesting soil. In these conditions, earthworms can be intoxicated by pesticides through dermal and digestive pathways. Because gut activity is important for the burrowing activity by ingestion alterations of the digestive system is very likely to have impacts on the individual himself but also indirectly on the environment (burrow structure).

To study alterations due to pesticides or pollutants, we focused our attention on the crop/gizzard complex, a part of the earthworm gut equivalent to the stomach in vertebrates. The crop/gizzard preparation is dissected away from the animal and immersed in a physiological saline solution. The mechanical activity is recorded using force-displacement transducers. Preliminary experiments indicate that the isolated crop/gizzard preparation exhibits spontaneous contractile activity. Phasic contractions occurred at a frequency of 1 to 4/min and developed a tension of 100 to 200 mg. This activity is not of neural origin since it was not inhibited by tetrodotoxin. Acetylcholine (0.25 to 1×10^{-7} M) and noradrenaline (0.05 to 1×10^{-6} M) increased both the force and frequency of contractions. The effects of acetylcholine are abolished by atropine.

This preparation emerges as a promising tool to test the action of pollutants/pesticides on digestive motility *in vitro* using earthworms coming from soils with different agricultural practices. Associated with behavioural and biochemical studies already performed in the laboratory, this preparation will provide relevant additional information on the effects of pollutants at different biological levels.

Soil ecosystem recovery following managed and unmanaged bioremediation of a terrestrial crude oil spill

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In the exploration and production of crude oil a terrestrial spill of oil and/or associated brine is not an uncommon occurrence. Once the spill has taken place it must be remediated or “cleaned” in order to restore the economic and/or aesthetic value of the impacted land as well as preventing further contamination of soil, groundwater, and surface waters by transport of contaminants off site. But how clean is clean? One view is that the soil ecosystem is “clean” when the ecosystem is sufficiently restored to support its previous use or an acceptable alternate use. The Integrated Petroleum Environmental Consortium (IPEC) is studying the effects of original contamination and the remediation process on grasslands soil ecology for spills of crude oil and brine. A lack of information on the ecological risk of oil and brine spills can lead to overly conservative and unnecessarily costly eco-based regulations. An understanding of potential ecological impacts will be part of any risk-based decision making process for management of accidental spills of produced fluids and make for better use of limited resources.

The J6 crude oil spill site is located in The Nature Conservancy’s Tallgrass Prairie Preserve, Osage County, Oklahoma, USA. Contamination resulted from a pipeline break on January 6th, 1999 releasing about 70 barrels of dewatered crude oil. Immediately downslope of the pipeline it contaminated an area of about 930 m² (J6N). The crude oil then flowed down a gully in a lease road and contaminated another area of the prairie (about 440 m², J6S). The initial total petroleum hydrocarbon (TPH) concentration in J6N was about 33,500 mg/kg and in J6S, 4,800 mg/kg. For the purpose of treatment comparison, each of these sites was divided into fertilized and non-fertilized sections. Further, for comparison, two types of controls have been used. One is unimpacted prairie disturbed by tilling and unimpacted and undisturbed prairie.

This paper discusses the results of quarterly analysis of hydrocarbon concentration (as TPH) and ecological indicators such as phospholipid fatty acids (PLFA), 16S rDNA (PCR amplification followed by denaturing gradient gel electrophoresis), nematode populations, revegetation, and various nutrient analyses.

The crude oil-impacted areas have shown significant TPH reduction with all TPH levels now less than 500 mg/kg. However, there have been no statistically significant differences in the rates of hydrocarbon removal with fertilizer addition in either J6N or J6S. Every ecological indicator though shows that the non-fertilized section of J6N lags behind the fertilized section in terms of recovery of the impacted soil ecosystem. The fertilized and non-fertilized sections of J6S, which received less hydrocarbon contamination, have exhibited comparable rates of recovery.

Invasive earthworms vs. other native invertebrates as conduits of heavy metal pollutants into the food web: A case study monitoring Salamanders in Pennsylvania, USA

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The last glaciation eradicated the native earthworm fauna of Canada. With the advent of European settlers earthworm species native to the old world started to invade North America. Since then earthworms have changed the structure of North American soils dramatically. Surprisingly little is known about the impact of this invasion on the indigenous soil fauna. In western Canada large areas still are free of European earthworms but rapid colonization has been documented during the last decades. The most rapidly spreading earthworm species include the epigeic *Dendrobaena octaedra* and the mineral soil dwelling *Aporrectodea caliginosa*, *Lumbricus terrestris*, and *Octolasion tyrtaeum*.

In the present study mineral soil dwelling species were used in field and laboratory experiments to study their effect on microarthropod communities in aspen forest soils near Calgary (Alberta; Canada). Generally, microarthropod groups were detrimentally affected by earthworm activity due to the processing of organic material and mixing of mineral soil with organic matter. The fact that earthworms, collembolans and oribatid mites feed on similar food resources led to competition for food resources. In comparison, densities of microarthropods in treatments with earthworms were similar in litter and earthworm casts, and in organic and mineral substrates, whereas abiotic and microbial properties of these substrates differed significantly. This indicates that in addition to earthworm-mediated changes in food availability and competition, microarthropods were affected directly by mechanical disturbances due to burrowing, feeding and casting of earthworms. Disturbance by earthworms was very strong in the laboratory systems leading almost to extinction of oribatid mites in treatments with two earthworm species.

Lombricomposting in ensilaged coffee pulp

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The coffee pulp is an important by product of the coffee industry which can have a negative impact on the environment if it is not treated. Since 20 years this substrate when it come from humid processing had been treated by vermicomposting. Traditionally this livestock is not ensilaged before it is submitted to vermicomposting. As ensilage is known to keep many of the quality of the fresh livestock, we wanted to observe if the earthworm community performed better in an ensilaged coffee pulp inoculated with a lactic bacteria (strains Nat b and L08 20b)UAMI/IRD). For that 4 treatments were established: coffee pulp ensilaged with the lactic bacteria (PLN & PLL), coffee pulp one year old without any innoculum and fresh coffee pulp per treatment there was 4 replicates. In each of this feedstock a known community of vermicomposting Earthworms, *Eisenia andrei* (bouché 1972) *Perionyx excavatus* (Perrier 1872) and *Dichogaster* sp, was introduced. Every 28 days during 4 months a sampling was performed in the bed to measure the earthworm biomass and density. At the end of the experiemt the vermicompost obtained was chemically characterized to observe which treatment produced the best product.

We observed that there was no significant differences in the earthworm community in density, biomass and species proportion among the e 4 treatments; although a tendency was observed that the biomass and density of the 3 earthworms community were higher in the one year coffee pulp. Besides the vermicompost from non inoculated feedstock seem to have better physicochemical characteristics than the inoculated treatment. Thus we don't recommend to ensilage coffee pulp with lactic bacteria because the earthworm community is less than in the traditional feedstock and the resulting vermicompost does not get any improvement in its quality.

Enzyme activities of earthworms, casts and soils: Impact of heavy metals

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Earthworms are one of the most important groups of soil animals involved in decomposing litter and in incorporating plant residues in the upper soil horizons. Their great importance in the nutrient cycle is uncontested. Metal pollution may disturb soil ecosystems by affecting structure of soil invertebrate populations. Successful protection of communities demands knowledge of the ecophysiology of metals in invertebrates in particular earthworms and their susceptibility to metal intoxication. The aim of this present study was to determine the effects of a heavy metals (Zn, Cu, Pb, Cd) on enzyme activities present in the soil, casts and the digestive tracts of earthworms (*Aporrectodea caliginosa*). The site studied, located in Nivelles (northern France) was a field currently used as pasture. On this site, an ancient country road was constructed using wastes from the metallurgic industry during the second world war. A sharp gradient of pollution was observed from the road (Zn > 19000 mg Kg⁻¹, Pb > 2000 mg Kg⁻¹, Cd > 11 mg Kg⁻¹, Cu > 400 mg Kg⁻¹) to the unpolluted area.

Soil samples and earthworms were collected along this country road and in the unpolluted area. A typology of these samples, has been established, based upon their enzymatic characteristics. This typology allowed to compare the functional aspects of the different samples (soil, casts and earthworms). The criteria for choosing the enzymes assayed were based on their importance in nutrient cycles and organic matter decomposition. In total 9 enzymes were tested (Arylsulphatases, glucosidase, -glucosidase, -xylanase alkaline and acid phosphatase, N-acetyl-glucosaminidase FDA and Laminarinase). This assay, therefore, provided a broad-spectrum indicator of soil biological activity.

To compare the results a Principal Component Analysis was realized. The position of the samples along the first two PCA axes showed that the soils (in particular polluted soils) were very clearly different from the other samples. In comparison with the casts and earthworms, the soils presented a broad enzyme profile.

A similarity dendrogram was used to graduate oppositions between samples. The first section segregated soil samples from all other samples. This opposition resulted from a wide enzyme profile. The second section regrouped casts and earthworms. This section was subdivided into two clusters distinct ie casts and earthworms

The enzyme activities measured in the unpolluted soils were significantly lower than those measured in the polluted soils. This result could be linked to the rate of organic matter which was lower in the unpolluted soil. Casts and earthworm enzyme profile were mainly characterised by high phosphatase activities and the absence of several enzymes which were detected in soil samples (arylsulfatase, FDA). This result indicated that gut passage affected the soil enzyme profile. Enzyme activities of casts originated from polluted soil were not significantly different from enzyme profile of casts built with unpolluted soil. Modifications of enzyme activities during the gut passage were not affected by heavy metal pollution. Almost no significant difference was observed between earthworms collected in the polluted area and earthworms collected in the unpolluted area. The digestive metabolism was not affected by accumulation of heavy metal in earthworm tissue.

Influence of soil type on microelement contamination effects on the structure of nematode assemblages

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Long-term effects of an artificial microelement pollution are studied in different localities of various soil conditions in Hungary. From the results influence of two different soil types on pollution effects (Cr, Se and Zn) is presented here. Site one (Nagyhörcsök) is characterized by a calcareous loamy chernozem soil, while site two (Órbottyán) is a calcareous sand. Initial nominal pollution levels at both sites and each element were equal to 90 mg·kg⁻¹. The microelements were given 4-8 years prior to nematode sampling, respectively. The concentration levels of each element available at the time of sampling were comparable among the two sites. The crop grown in the sampled vegetation period was sorrel (*Rumex rugosus* L.). The studied nematological parameters were as follows: abundance, generic richness, Maturity Index (MI), Structure Index (SI), c-p and feeding group distribution (with respect to the responses of plant nematodes to the quantity of crop biomass) and Rényi diversity profiles.

Regarding MI and SI values, Se treatment caused a decrease compared to the control. This decrease was more pronounced in the sandy samples. Diversity ordering revealed a difference between the control and the Se-plots, as well as between the control and the Cr (VI) treatment in the sandy site. Zn treatments and Cr in the chernozem site did not cause a considerable decrease of diversity profiles. In themselves, the sandy controls were characterized by higher diversity values, than the ones in the chernozem site. On the other hand, Se appeared to have a more remarkable effect on nematode assemblage of the sandy site.

In conclusion, although the nematode assemblages of the two sites differed markedly (with an apparently more “mature” nematofauna in the sandy site), there were no great differences detected among the effects of the microelement pollution. The details of this finding will be discussed in the presentation, in relation with the crop biomass data.

Does changing the taxonomical resolution alter the value of soil macroinvertebrates as bioindicators of heavy metal pollution?

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Ecological indicators are taxa that are affected by, and indicate effects of, anthropogenic environmental stress or disturbance on ecosystems. There are evidences that some species of soil macrofauna (i.e. diameter >2mm) constitute valuable biological indicators of certain types of soil perturbations. This study examined the ability of soil macrofauna to indicate the effects of heavy metal pollution and the effect of changing the taxonomical resolution upon the indicator value. Macrofauna was sampled in a set of sites encompassing different land-use systems (e.g. forests, pastures, crops) and different levels of pollution. Indicator taxa were searched for using the IndVal index proposed by Dufrêne and Legendre [1]. Of the 339 morphospecies recorded, 21 displayed a significant indicator value (6%). When the species were aggregated to form families (66) a total of 17 units were significantly associated to a site type or to a group of sites (a proportion of 26%). Associating the species into 35 broad ecological assemblages led to 17 indicator groups (49%). Because identifying fauna at the family or at the ecological group level is easier, it may seem preferable to use those levels of resolution. In addition, the proportion of taxa that are significant indicators is higher using broad levels of resolution. However, our results show that the indicator taxa did not have the same meaning as we changed the taxonomical resolution. As an example, some species that were specialist of a given land-use type were aggregated into a family that was found to be generalist. Therefore caution is needed and we believe that using different taxonomical resolutions in the same analysis may prove useful. Much more information and field studies are necessary to determine how and to which extent soil macrofauna can be used as indicator of soil system disturbance or stress.

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Introducing deep burrowing earthworms into arable heavy clay: Not for the impatient

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The earthworm *Lumbricus terrestris* L. provides valuable ecosystem services in arable soils e.g. by moderating water and element cycles. Where *L. terrestris* is absent, field inoculation could be used to promote population growth. Such practices appear particularly well motivated, if favourable changes in field management occur simultaneously.

In 1996, we carried out *L. terrestris* inoculation at a field site on heavy clay soil in southern Finland. *L. terrestris*, whilst absent from the field and immediate surrounding areas, was present in many other local soils. The study area consists of four adjacent plots (33 m x 140 m), surrounded and separated by permanent grass strips. Sub-drainage of the field was improved in 1991 and in 1992 ploughing was replaced with stubble cultivation in two of the plots. Earthworm inoculation units were established in May 1996. Each 8 litre unit of soil and horse manure as feed, received five large, field collected *L. terrestris*. Units were kept at 16°C until inoculation in October 1996, when they contained, on average, three large *L. terrestris* and 23 cocoons. Inoculation of 82 units took place at one field margin in three parallel (135 m) transects running through the four plots, inoculation points being separated by 5.5 m. The first transect was in a permanent grass strip just outside the cultivated area, the others were inside the field at 6 and 8 m distance from its margin. Border strips between plots were also inoculated.

Results from follow-up in September 1998 showed that *L. terrestris* had persisted locally at inoculation points in the field boundaries and border strips (maximum density 27 ind. m⁻²) with evidence for short range (1.5 m) dispersal. The majority of individuals were juveniles hatched from inoculated cocoons. Inoculation seemed to have failed in its main goal: no *L. terrestris* were located in the cultivated area.

In October 2003 further monitoring took place. Spatial distribution in the field boundary and plot borders was found to resemble that from 1996, with maximum density at 37 ind. m⁻². In border strips individuals were obtained at 4 m beyond the nearest inoculation point and midden observations provided evidence for 8 m dispersal from inoculation points. *L. terrestris* was also found inside the field, from three of six points sampled at 12 m distance from the field margin (max density 4 ind. m⁻²).

Initial failure of *L. terrestris* settlement inside the field indicates that conditions there were difficult for the species. Initiation of population growth inside the field may have required the population density at the plot margins to reach a threshold level, to act as a source of colonists. Surviving field immigrants may then have been individuals settling at favourable pockets of soil, such as areas of low water table near sub-drains.

Results suggest that limited dispersal was one reason for the absence of *L. terrestris* from the study site and that inoculation in that respect was justified. However, the road to population establishment looks long and calls for patience and critical evaluation of the inoculation practice.

Effects of the earthworm *Allolobophora caliginosa* on the fate of parathion in natural soil

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Earthworms as ecosystem engineers influenced a great number of physical, chemical and biological processes in soil. Pesticides can modify earthworm behaviour and decreases earthworm activity. In turn, the fate (adsorption and degradation) of pesticides can be modified by earthworm activities directly (through physical processes) or indirectly (through interactions with micro-organisms). To test this assumption, an experiment was carried out with radio-labelled methyl parathion as model pesticide. The fate of parathion was followed in soil (30% water content) 30 days in presence or absence of worms (*A. caliginosa*) in the laboratory (12°C). Globally the fate of the insecticide was not greatly modified. In presence of worm, the percentage of parathion that was found as bound residues was slightly increased after 30 days (from 50 to 55%), the percentage of insecticide that was degraded was slightly decreased (from 20 to 15%) whereas the percentage of adsorbed parathion was stable. We observed that the presence of *A. caliginosa* significantly increased the degradation of organic matter. This could to be the explanation of the differences observed concerning the fate of methyl-parathion under our experimental conditions.

Effects of Almalyk Industrial Complex contamination on soil free-living nematode population

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The Almalyk Mining and Melting Industrial Facility in Uzbekistan is one of the major heavy metal industrial complexes that, during many years of activity, has been found to contaminate the soil system with Cd, Pb, Cu, As, and Zn, with decreasing impacts along a 15 km transect.

The objective of this study was to estimate the degree of heavy metal impact on the structure and trophic composition of the soil free-living nematode population along the emission gradient in the upper (0-10 and 10-20 cm) soil layers.

The degree of heavy metal impact was found to have a decreasing negative effect on the nematode population along the emission gradient. However, the percentage of different trophic groups of the total population was found to belong to one of two main patterns: (1) high percent at the emission source, with decreasing values toward the end of the transect (fungi-feeders, plant-parasites); and (2) few individuals at the source, with increasing values toward the end of the transect (omnivore-predators, bacteria-feeders).

The maturity index, which is known to reflect soil biological health, was found to be the most sensitive tool to measure changes in contamination levels for the upper (0–10 cm) and deeper (10–20 cm) soil layers. These results suggest that a linkage exists between contamination level and nematode population composition and activity.

Vermicomposting of wastes derived from food processing industries: evaluation of parameters of vermicompost quality

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The degradation of organic wastes using aerobic and biological techniques (composting and vermicomposting) has become a solution which allow the transformation of those wastes into valuable products as organic amendments. However, to obtain a good merchandising of those amendments, it is critical to obtain an index which reflects the quality of the final product. In this work, the effect of earthworms (*Eisenia fetida*) on the transformation of some industrial organic wastes over a range of quality parameters (C/N ratio, microbial activity, humic and fulvic acids, phytotoxicity) was evaluated. The main objective was to determine which of those parameters reflects better the correct development of the vermicomposting process.

Three kind of industrial sludge were used in the study, the fatty fraction and the solid fraction of a sludge produced by a dairy factory, and the sludge from a fishery transformation factory. All the sludge were mixed with two bulking agents: wheat straw and gorse and these mixtures were pre-composted in a bio-reactor before earthworm's inoculation.

For each treatment 8 plastic vessels, 500 ml each, were used. In one side, wet vermiculite, a substrate which allow the survival of the earthworms but gives them no food, was disposed. The other side was filled with the different waste mixtures. Five vessels were inoculated with 5 immature specimens of *Eisenia fetida*, into the vermiculite zone; the other three vessels, without earthworms, served as control. Earthworm mass, the number of cocoons they produced, the hatching success and the number of hatchlings per cocoon were recorded biweekly during eight weeks. At the end, the different waste mixtures were analysed.

In the treatments where growth and reproduction of earthworms were good we found a lower microbial activity and a higher humic/fulvic acid ratio. The relationship between earthworm growth and development and the parameters of quality analysed showed that microbial activity (measured as microbial respiration) and the ratio between humic and fulvic acids are better indicators of the correct development of the vermicomposting process than other parameters as C/N ratio or phytotoxicity assays.

Earthworm and enchytraeid communities along the pollution gradient near Olkusz (southern Poland)

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The effect of heavy metal pollution on Oligochaeta (*Enchytraeidae* and *Lumbricidae*) populations was studied along the pollution gradient in vicinity of Olkusz (southern Poland). Study plots were situated in mixed pine forests 3.5 km, 2.5 km, 3.9 km, 7.9 km and 31.9 km (reference site) from the source of pollution (zinc smelter). The study plots differed with metal concentration in humus layer. The animals were collected in November 2001, April 2002, June 2002 and November 2002. Twenty soil samples (16.6 cm²) for enchytraeid and ten soil samples (25x25 cm²) for earthworm population density and species composition determination were taken from each site at every sampling occasion. *Enchytraeidae* populations consist of nine genera (*Achaeta*, *Buchholzia*, *Cognettia*, *Enchytraeus*, *Enchytronia*, *Fridericia*, *Henlea* and *Mesenchytraeus*) and 18 species. Dominating enchytraeid species in all study plots was *Cognettia sphagnetorum* (approx. 90%), except of the most polluted site, where *Enchytraeus*, *Fridericia* and *Henlea* were the most common. The highest species diversity (Shannon-Wiener index) and heterogeneity (H/lnS) were stated on the most polluted plot. There were differences in enchytraeid densities between sampling occasions (the highest density was in November 2001). The highest mean densities were found in reference plot (16 333 individuals /m²) and lower in the most polluted plot (3932 individuals /m²). A correlation between distance from pollution source and enchytraeids density was found. In April densities were very low and no differences were found along the transect. Earthworm populations consist of 3 epigeic species: *Dendrobaena octaedra*, *Dendrodrillus rubidus* and *Lumbricus rubellus*. The most abundant species was *Dendrobaena octaedra*. Earthworms densities in all plots sampled were low (3.2 individuals /m² in reference plot – 11.7 individuals /m² in polluted plots), therefore it was difficult to judge from this parameter on influence of pollution on earthworms populations. The highest concentrations of Zn, Cu and Cd in: humus layer, enchytraeids and earthworms were on the most polluted plot. Enchytraeids are suitable animals for monitoring studies because their importance in soil processes, especially in habitats where earthworms are scarce, high densities in various forest types, as well as easy collection and extraction from soil.

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Are earthworms - *Dendrobaena octaedra* - adapted to polluted environments?

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No evidence is available in the literature on adaptation of earthworms to life in polluted environments. On the other hand, examples of fast selection of *E. fetida* metal tolerant strains in the culture were reported. Therefore one can suspect that living in polluted soil may also cause an adaptive selection for metal tolerance. The present experiment was designed to answer the questions: i. do the animals originating from differently polluted forests (P generation) and cultured in unpolluted (“clean”) soil differ with some life-history traits? ii. what is their response to culturing in a cadmium polluted soil?; iii. which of the observed differences are inherited by the offspring (F1 generation)? Adult individuals of *Dendrobaena octaedra* were collected in June 1996 in three mixed-pine forests (*Pino-Quercetum*): the most polluted one near Olkusz, the moderately polluted Niepołomice Forest (both Southern Poland) and the relatively unpolluted Kampinoska Forest (Central Poland). In the laboratory earthworms were cultured in artificial soil (OECD 207). Two series of cultures were established: “clean”, with animals kept in artificial soil and “cadmium” with animals kept in artificial soil contaminated with cadmium. The experiment was continued until the last individual of F1 generation died (four years). In both generations cadmium concentration, body mass, reproduction and survival were examined. Although the parent generation of animals originating from polluted Olkusz forest demonstrated an increased cadmium accumulation, this effect cannot be regarded as an indication of a heritable (adaptive) resistance, because in F1 generation the cadmium concentration levels within series (“clean” and “cadmium”) was similar among populations (Olkusz forest, Niepołomice Forest, Kampinoska Forest). In P generation the least detrimental effect of cadmium on cocoon production was observed in the most polluted Olkusz population. The reproductive allocation (total mass of cocoons divided by the parent mass) was highest in Olkusz population (both in “clean” and “cadmium” soil). In F1 generation there were no differences in reproductive allocation between populations cultured in “clean” soil, while in “cadmium” soil, like in parent generation, the highest reproductive allocation and the weakest effect on reproduction were in Olkusz forest population. The most sensitive period in earthworm life is juvenile stage. Cadmium applied early in earthworms life has detrimental effect not only on the body mass, the age of first reproduction, the cocoon production but on the proportion of reproducing animals and survival as well. In P generation the longest survival characterized animals originating from Olkusz forest and the shortest the ones from Niepołomice Forest. In “cadmium” soil the highest survival demonstrated the animals from Olkusz. In F1 generation cultured in “clean” soil animals from all populations survived similarly long. Differences appeared between “cadmium” animals. In earthworms from Olkusz population mortality was much lower than in all other (similarly like in parent generation). Better survival of Olkusz animals collected in the forest (P generation) may be explained as a reaction to transfer from polluted into unpolluted soil. The observed heritable higher resistance to cadmium in Olkusz population seems to be an evidence of adaptation of *D. octaedra* to polluted environments.

Effect of heavy metals on soil chemical and biological activity in the vicinity of the Almalyk Mining and Metallurgical Complex, Uzbekistan

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The Almalyk Mining and Metallurgical Complex is one of the main sources of air pollution in Uzbekistan, responsible for 13% of all of Uzbekistan's air emissions from stationary sources. As one of the largest mining companies in Uzbekistan, it produces refined copper, gold, silver, lead, metallic zinc, and other products.

The aim of this project was to study the heavy metal impact on the soil microbial and nematode population along the emission gradient from the Almalyk industrial complex at 4 locations: 0, 5, 10, and 15 km along the downwind transect. At each location, soil samples were collected (n=5) from the upper layers (0-10 and 10-20 cm) and the soil environmental variables (soil moisture, organic matter, N, Ca²⁺, K⁺, Na⁺), level of heavy metals (Cd, Cu, Pb, Zn, As), and biological activities (CO₂ evolution, microbial biomass and nematode population) were determined.

Significant differences between soil chemical and biological properties by increasing distance from the source to downwind direction and depth were observed. A significant difference in the total number of nematodes, organic matter, and microbial biomass contents was found along sampling locations (p<0.0001) and depth (p<0.01). The highest number of nematodes and microbial biomass content were observed in soil samples from the distances 10-15 km. Respiration displayed similar results to the microbial biomass. The derived metabolic coefficient - qCO₂ revealed significant differences by distance, confirming environmental stress in first and second locations. The microbial echophysiological coefficient qCO₂ (C_{mic}/C_{org}) was lowest in soils with high heavy metal content. This suggests that the immobilization of organic matter as microbial biomass can be more difficult in polluted soils than in unpolluted ones.

Thus, the emission of a copper smelter has resulted in a marked accumulation of heavy metals in soils near the smelter through atmospheric deposition. High heavy metal content in soils resulted in decrease in N, K, Na concentration, soil moisture, total organic carbon amounts in soil, and effect on total number of nematodes, soil respiration and microbial biomass content.

Influence of chemical agents commonly used for soil fauna investigations on the stable C-isotopic signature of soil animals

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Within a long term carbon-project (FACE) at the Federal Agricultural Research Centre in Braunschweig, Northern Germany, the influence of atmospheric CO₂ enrichment on selected soil animals is determined at the Institute of Agroecology. The surplus CO₂ used within the field experiment has a certified ¹³C/¹²C ratio. Therefore the carbon of CO₂ enrichment can be detected in different compartments of the agroecosystem by use of stable C-isotopic signature (expressed as δ¹³C-value). Within this field experiment collembolans and nematodes were isolated from soil samples by extraction. Usually different chemicals, which represent potential carbon sources, are used for fixation, preservation, bleaching etc. Therefore these agents could modify the ¹³C/¹²C-ratio of animal tissue. This methodical problem is the key point of the present contribution. Exemplarily the influence of commonly used chemical agents on the C-isotopic signature of collembolans is presented for monoethylenglycol, ethanol and lactate. Furthermore, results on effects of triethanolamin, formalin and glycerine on the C-isotopic signature of nematodes will be shown. Finally, possibilities will be discussed to solve such problems.

**Management of plant – parasitic nematode *Meloidogyne incognita*
(Kofoid and White, 1919) Chitwood, 1949 by vermicompost in
pulse – crop, *Vigna mungo***

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The plant – parasitic nematode (PPN) *Meloidogyne* spp. is known to affect many crops such as rice, banana, corn, vegetables and pulses in tropical countries, especially in India. The yield loss in blackgram, *Vigna mungo* due to infestation of *M. incognita* is about 40-46%/Yr. Black gram is an important source of protein for most of the South Indian population. Among the biological control measures, application of vermicompost obtained by recycling sugar industrial wastes have shown the PPN – *M. incognita* to be significantly reduced (More than 50%). The role of development of inimical physico-chemical and biological conditions of the soil, resistance development in plants due to enhanced nutrients and enhanced and sustained release of organic acids like humic acid and ammonia, phenol and fatty acids and increased number of saprophytic nematodes in the regulation of PPN are discussed.

Key words: Plant parasitic nematode – *Meloidogyne incognita* – Vermicompost - pulses

Regulating role of lumbricid macrofauna in atrazine (herbicide) biodegradation in cultivated temperate soil

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In the last ten years accelerated degradation of atrazine has been evidenced in agricultural soils submitted to repeated application of the herbicide. A variety of atrazine degrading bacteria have been isolated. The genes encoding catabolic enzymes involved in atrazine mineralization have been sequenced and characterized for *Pseudomonas* sp. strain ADP (*atzA*, *B*, *C*, *D*, *E* and *F*).

The impact of environmental factors on the survival and activity of atrazine degrading bacteria is not well known. The earthworms are considered as soil engineers as they greatly disturb both the microbial compartment and the physico-chemical properties of the soil they visit. Few studies have reported the role of earthworms on atrazine mineralization but medium and long term studies (more than 2 months) showed that atrazine mineralization was reduced in the presence of earthworms.

This study aims to precise the interaction between earthworms and the atrazine degrading community and its activity in soil microsites. To examine the extent and the mechanisms by which earthworm macrofauna contribute to reduce atrazine mineralization in a maize cropped soil, we distinguished representative soil microsites of earthworm activities (gut contents, casts, burrow-linings). To underline the effects, the soil was inoculated with *Pseudomonas* sp. strain ADP and pre-treated with atrazine. To simulate more realistic earthworm community conditions, the combination of two ecological types of worms that are commonly found in temperate cropped soils was used, *i.e* the epi-anecic species *L. terrestris* and the endogeic species *Aporrectodea caliginosa*. We then investigated the structure of the bacterial community, the atrazine degrading activity and the quantities of *atzA*, *B* and *C* genes in the soil microsites.

We showed that the earthworms modified the structure of the bacterial communities of the soil. Accelerated mineralization of atrazine was not observed in the ingested soil even when inoculated with *Pseudomonas* sp. ADP. The *atz* genes quantities were inferior in the biostructures. The slow down of atrazine mineralization in the biostructures with *Pseudomonas* sp. ADP could be due to a controlled expression of the *atz* genes.

SESSION 7

Functional Groups and Valuation as Indicators of Soil Fauna

ORAL CONTRIBUTIONS

Meta-analysis of enchytraeid responses to climate change. Implications for C cycling

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Increasing concentrations of greenhouse gases are expected to raise the mean global temperature up to 5 oC by year 2100 and the environmental change scenarios suggest that the responses of biomes to climatic variations will lead to changes in biodiversity. The expectation that atmospheric warming will be most pronounced at higher latitudes means that Arctic and montane systems will be particularly influenced by climate change. Enchytraeids show a worldwide distribution but are particularly abundant in these cold and wet environments, where they frequently dominate the soil fauna community in terms of live biomass.

Because most of the annual carbon (C) turnover occurs in the soil upper layers in these systems research on enchytraeids is seen as increasingly important as their key role in soil C transformations at high C storage sites unfolds and the feedbacks between climate and soil C stores become increasingly important in predicting future climate.

In order to predict the impacts of climate change on this important group of soil organisms we have reviewed data from 45 published papers on the effects of abiotic factors on total animal numbers, vertical distribution and age groupings of all enchytraeid species analysed together and, more specifically, concentrating on the individual species, *Cognettia sphagnetorum* for which a large number of individual studies exist. Using a combination of meta-analysis and conventional statistical techniques the results show that the total population of enchytraeids is strongly influenced by local climate, with temperature and rainfall inputs having a significant influence on total numbers of enchytraeids (all species). Highest total numbers of enchytraeids are associated with temperate rainy climates, with rainfall in all seasons, whereas *C. sphagnetorum* numbers appear to strongly decline with hot, dry summers. Although enchytraeids could be found in locations with annual temperatures above 25 oC degrees, some genera such as *Bryodrilus*, *Mesenchytraeus*, *Cernosvitoviella*, *Stercutus* and the species *Buchholzia fallax*, have never been recorded at sites with mean annual temperatures higher than 12.5oC. Indeed, *C. sphagnetorum*, and the other species within the genus *Cognettia*, have never been reported from areas with an average annual temperature above 16 oC. This has important implications for the future distribution of these species and, consequently, for carbon dynamics in moorlands and tundra biomes where these species are dominant. Specifically, in rich organic soils, enchytraeid communities are usually dominated by *Cognettia sphagnetorum* which may represent up to 70% of the total soil fauna biomass. Climate change manipulations have demonstrated the particular sensitivity of this species to temperature and moisture change, with important implications for carbon and nutrient cycling.

The effects of two pesticides in semi-field and field tests under tropical conditions (Amazonia, Brazil)

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Usually, the environmental risk of pesticides is assessed using tests which are designed according to temperate conditions. For the compartment soil several laboratory tests are available while only few methods have been standardised on the semi-field and field level. In fact, only one ISO guideline (the Earthworm Field Test; ISO 11269-3) is fully accepted. Recently, the litter-bag test, measuring the effects of pesticides on organic matter decomposition in the field has been proposed to OECD (EPFES 2002). In parallel, the use of Terrestrial Model ecosystems (TMEs) as a terrestrial microcosm method for the semi-field level has been investigated in an EU-wide interlaboratory comparison study.

However, since temperate and tropical conditions (e.g. in terms of soil types, temperature and species) differ greatly, it is doubtful whether the results of “temperate” tests can be extrapolated to tropical ecosystems. To clarify this point, ecotoxicological studies were performed within the Brailian-German project SHIFT (Studies on Human Impact on Floodplains and Forests in the Tropics). In this contribution, a TME study and a field test done with a fungicide (carbendazim) and an insecticide (lambda-cyhalothrin) are described. The field site was an abandoned rubber plantation located 30 km north of Manaus (Amazonas, Brazil). Intact soil cores for the TME study were extracted from the same site. The soil was a Ferralsol (Yellow Latosol) with a low pH and few nutrients. While in different runs of the TME study native as well as standard test species were introduced, in the field study the abundance and diversity of the local fauna were used as measurement endpoints. In addition, the functional endpoints organic matter breakdown and the feeding rate were measured using the litter-bag test and (partly) the bait-lamina test. From a technical point of view, the test methods originally developed for temperate conditions could easily be modified for the conditions of Amazonia.

Summarising the results of these tests it seems that both pesticides can have an impact on organic matter breakdown at field relevant concentrations. In addition, some organism groups were significantly affected on both investigation levels. Carbendazim, known to be toxic for oligochaetes, decreased the abundance of the introduced earthworm species *Pontoscolex corethrurus* in the TMEs and of a native species (*Andiorrhinus amazonicus*) in the field. The insecticide lambda-cyhalothrin was toxic to isopods and millipeds in the TMEs, but did not affect arthropods in the field one year after application; probably due to recolonisation of the relatively small field plots.

Besides presenting the modified test methods and the results of the various test runs, a preliminary risk assessment of these two pesticides under tropical conditions is intended in this contribution.

The work presented here was supported by the Brailian (CNPq) and German (BMNF) government.

Uranium production effects on soil macrofauna in South-Eastern Siberia (Russia)

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Mining and milling activities of the Priargunsky Mining-Chemical Production Company (Chita Region, Russia) continuing since 1968, have resulted in an enrichment radionuclides and heavy metals in adjacent steppe soils by a factor of up to 600. Uranium concentrations ranged from 2.3 to 1474 mg/kg, thorium 1.5-17, molybdenum 1.1-125, lead 20-47.7 mg/kg. A number of attendant pollutants (arsenic and other heavy metals) have high concentrations in the soil as well. There were four sites chosen for the study, one reference and three polluted ones. The latter situated in the vicinity of the hydro-metallurgic plant, the sulphuric acid producing plant and close to the foot of the rock dump of uranium-molybdenum ore mine. To estimate the effects of this pollution on soil-living macroinvertebrates, pitfall trapping and core sampling were applied. The element composition of four beetle species, *Poecilus gebleri*, *P. fortipes* (Carabidae), *Blaps rugosa* (Tenebrionidae) and *Nicrophorus investigator* (Silphidae), was analysed. Soil macroinvertebrates had 3-37 times lower abundance and biodiversity at the contaminated sites compared with the control. Ground beetle communities at the contaminated sites were depressed compared to a control site. The concentrations of uranium and arsenic in beetles collected at the contaminated sites were 2-41 and 2-26 times higher, respectively, than in the control site. The study shows that if a pollutant (U in this case) is present in an extremely high concentration in the environment, even carabid beetles (not good accumulators), concentrate large amounts of it in their bodies. There is strong evidence that the contamination caused by uranium production has severe negative biological effects on important groups of the soil food web.

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A comparison of fauna in soils planted with *Bt* toxin-expressing transgenic maize and an isogenic control, with and without additional insecticide, in a glasshouse study

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The experiment described is a component of the EU-funded project entitled 'Soil ecological and economic evaluation of genetically modified crops' (ECOGEN, www.ecogen.dk). The overall project has an emphasis on maize genetically modified to express the *Bacillus thuringiensis* toxin (Bt maize) and encompasses a tiered approach of single-species laboratory tests, glasshouse pot experiments, field studies at three sites, rule-based modelling and economic evaluation. This presentation details results from a glasshouse pot experiment. The experimental design was: 2 x maize lines ("the Bt-expressing MEB307" and "the isogenic Monumental"), 2 x soil types ("a clay rich" and "a silt rich" soil from the field sites in France and Denmark respectively), 2 x insecticide treatments ("with" and "without" a pyrethroid insecticide used to control European corn borer), 4 x sampling occasions ("start", "5 leaf" and "12 leaf" stages – which correspond to insecticide applications in the field, and "post-flowering"), with 5 x replicates. The parameters monitored at each sample were designed to mirror those measurements made at the field sites and to complement the single-species tests. We measured: mineral-N in the soil, microbial biomass and community structure (both by phospho-lipid fatty-acid analysis and community-level physiological profiling), protozoa, nematodes, microarthropods, litter-bag decomposition, and levels of Bt-toxin in both soil and plant material. At the time of abstract submission the experiment was approaching the first sampling occasion so no data were available for dissemination, but by the time of the colloquium we will have a good idea of the comparative effects of Bt-maize and insecticide on soil populations and processes in this pot experiment and be able to compare the results with data from the field trials of the same maize lines in the same soil types. This will provide an insight into the usefulness of the tiered approach in ecological GM risk assessment.

Biodiversity effects on soil processes explained by community composition; the importance of functional complementarity of species

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Current theory on the relationship between soil biodiversity and ecosystem processes emphasize on the importance of species richness or functional group diversity (Jones & Bradford 2001; Shrivastava 2002). However, the species-specific mechanisms of affecting a certain process should be taken into account as this may lead to a better understanding how communities affect soil processes. This will be illustrated by this study, which aimed to look at the functional diversity of species within one trophic group, the macro-detritivores, and their effect on decomposition processes. We hypothesised that species composition has a larger effect on soil process rates than species diversity.

To test this hypothesis, we performed a microcosm study with increasing diversity of macro-detritivores: 1, 2, 4 and 8 species per microcosm. The species were drawn from a pool of isopods, millipedes and annelids from a river floodplain. Monocultures of all eight species were included in the design to be able to quantify their potential effect on soil process rates. Several multi-species treatments were included, i.e. five 2-species and four 4-species treatments, to assess species composition effects on process rates.

We measured the effect of community diversity and composition on CO₂ production, total NO₃ and NH₄ production, leave litter fragmentation, vertical distribution of OM content over the soil profile, biomass of fungi and bacteria, and leave litter mass loss. Leave litter fragmentation and mass loss, and total CO₂ and NO₃ production, showed an asymptotic relationship with species diversity. Already at low diversity, i.e. 2 species, process rates were constant. However, high variance between the specific species combinations within a diversity treatment suggested strong compositional effects on processes. For some species combinations a higher effect on process rates was observed than expected from the potential effects observed in monocultures, suggesting the occurrence of facilitation. For other species combinations a lower effect than expected was observed, suggesting the occurrence of competition between species. Presence or absence of competition or facilitation could not be predicted from species numbers, but was, however, related to the functional differences between species.

With this study, we confirm that theories of how species diversity affects ecosystem processes cannot just be generalized, as they are dependent on functional identity of species in the community, including the presence of keystone species, and the process under consideration. Furthermore, we conclude that the species composition of a community, by complementarity of functional identities is the actual driver of important ecosystem processes.

No effect of habitat fragmentation on microarthropods in soil

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Habitat fragmentation is considered to be the major threat to biological diversity. In this study we investigated the effect of habitat fragmentation on the soil microarthropod community (Oribatida, Mesostigmata, Collembola). In a mixed oak (*Quercus robur*)-hornbeam (*Carpinus betulus*) forest the soil system was fragmented for 17 months using small closed microcosms (\varnothing 6cm) while the control site remained untreated. We tested the following five hypotheses: (1) the abundance of large species is more likely to decline than that of small species, as large species have greater fluctuations in their population densities than small ones; (2) the abundance of rare species of soil microarthropods will also decline faster than that of abundant species, because rare species are more likely to become extinct by stochastic processes; (3) the abundance of species at higher trophic levels (e.g. predators compared to saprophagous species) is expected to decline due to the fact that they are subjected to more intense population fluctuations than species at lower trophic levels. If the latter hypothesis is true another hypothesis arises: (4) species that are top-down controlled (e.g. collembolans) profit from reduced predator densities whereas species that have few enemies (e.g. oribatid mites) are little affected. Surprisingly, densities of most soil microarthropod taxa (Oribatida, Mesostigmata, Collembola) were not affected by habitat fragmentation over a period of 17 months. The density of the oribatid mite species did not decline significantly in the habitat fragments and therefore large species are not more likely to decline than small species. Furthermore, the habitat fragmentation did not alter species richness and rare species are not more likely to decline than common species. Also the structure of the oribatid mite and the collembola community was not influenced by habitat fragmentation. We suggest that due to the small body size and limited dispersal ability of microarthropods they inhabit isolated microhabitats and therefore are insensitive in respect to fragmentation. This contrasts above-ground communities, where the isolation of the habitat is often correlated with decreasing diversity and abundance.

Soil macrofauna as indicator of soil quality

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Interest in the quality and health of soil has been stimulated by recent awareness that soil is vital to the global ecosystems function. With the increasing pressure to produce more food, fiber and energy to meet world demands on a limited area, there is an unprecedented need to address global concerns about soil degradation.

During the last decades an important number of studies has been realised on soil macro-invertebrates as bio-indicators of soil quality. These studies revealed their high sensitivity and accuracy to reflect soil status and thus their adequacy to be used in bio-indication (Paoletti *et al.*, 1999; Lobry de Bruyn, 1997; Rodriguez *et al.*, 1998; Frouz, 1999).

The main disadvantage often outlined of using terrestrial invertebrates as a broad and rapid tool to evaluate soil status and environmental changes by a large range of actors is the difficulty found to identify species level.

The aim of this paper was to test the usefulness of higher taxa analysis at genus, family and order level to estimate the bio-indicator power of soil macro-invertebrates at these taxonomical levels compared to the species level.

For the sake of robustness four regions in France were sampled in which forest, grasslands and cropped systems represented a wide range of different situations.

A total of 630 samples of soil macro-invertebrates were collected and identified up to species level. Singletons and doubletons were removed from the data set. A correspondence analysis was performed at order, family and species level for each study site. Spearman's correlations were realized between the coordinates of the sites positions on the first two axis of the multivariate analysis. Results showed high correlations ($R=0.76$) statistically significant between the species and the family level for all study cases. Concerning correlations between order and family level there was a variable response between sites and even between axis. Two of four studied sites (Ile-de-France and Auvergne) showed a high correlation between orders and families ($R=0.82$), sites located at Bourgogne region showed a statistically significant correlation for the ecological factor highlighted by the second axis and in Centre region there was no correlation. The variability of the responses was associated to different management systems and to different axis.

Regarding these results it has been suggested that the family level could be used in bio-indication with soil macro-invertebrates.

SESSION 7

Functional Groups and Valuation as Indicators of Soil Fauna

POSTER CONTRIBUTIONS

Effects of tree species, fertilizer application and earthworm introduction on earthworm community composition in an ancient forest on acidified loess soil in central Belgium

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Ancient forest soils developed on loess are often very degraded from a soil physical and chemical point of view due to a long history of biomass extraction, beech monoculture and more recent phenomena such as compaction by skidders and acidifying depositions. This study evaluated the mid-term effects of integrated restoration of compacted and acidified forest soils combining tree species choice, fertilization and earthworm introduction. The research site is a tree species trial, comparing *Acer pseudoplatanus*, *Quercus robur* and *Fagus sylvatica*, established in 1906 in Zonien Forest, a 4400 ha peri-urban ancient woodland south of Brussels. Within this trial, a block experiment was established in 1992. Under the tree blocks random plots with six different treatments combining Ca, Mg, K and P fertilization with the introduction of endogeic and/or anecic earthworm species were laid out. Earthworm communities were sampled before and ten years after the introduction (in 1988 and 2002), using similar methods. Results show a striking shift in the earthworm community structure. Where in 1988 the community was dominated by epigeic species, it is now clearly dominated by endogeic species. The number of earthworms per m² has increased in all three blocks, but only under *Fagus sylvatica* significantly. Also the total earthworm biomass per m² only increased significantly under *Fagus sylvatica*. It has to be noted that in 1988, biomass and numbers of (mostly epigeic) earthworm individuals were already relatively high under *Acer*, and to a lesser extent, also under *Quercus*. Further examination of the results shows a strong correlation between tree species and specific endogeic species (i.e. *Allolobophora limicola* with *Acer*, *A. caliginosa* with *Fagus* and *A. rosea* with *Quercus*). Also some interesting conclusions could be drawn concerning the speed of migration of the respective species. It can be concluded that an integrated approach to soil rehabilitation - combining fertilization with earthworm introduction and tree species choice – can result in a shift from a dominantly epigeic to a dominantly endogeic earthworm community, and therefore, in an important increase of bioturbation in the topsoil.

Preference tests with collembolan on isogenic and Bt-maize

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Environmental impacts of genetically modified maize plants on the soil biota are poorly known. This is a matter of regret, because on average about 5-6 metric ton ha⁻¹ dead residues of Bt-maize enter into soil on more than 5 million ha worldwide. There is very few information about the differences in effects of decomposing isogenic and Bt-maize for soil animals, including collembolan.

Izogenic and Bt-maize (DK-440-BTY „Yielgard”) were grown in an experimental field in 2002. This genetically modified maize plant produces CryIA_b protein. The results of these experiments showed that the feeding activity of the soil animals was lower in the Bt-maize plot than in the control plot (measured by bait lamina test). This is why laboratory feeding experiments were set up with collembolan. Two main questions were addressed (i) whether collembolan are equally distributed on residues of isogenic and Bt-maize (ii) whether collembolan show feeding preference to one of the maize types.

Three collembolan species, *Folsomia candida*, *Heteromurus nitidus* and *Sinella coeca* were used in the experiments. Paired-choice assays were conducted in Petri-dishes. The number of animals on the plant was counted in distribution test and the number of fecal pellets near by the food plant served as representative of the food consumption. Tests were performed with single animals per arena and with animals in groups. Food preference of the starved *F. candida* was also tested.

H. nitidus avoided Bt-toxin containing maize leaf pieces, but the other two species did not. *F. candida* fed less Bt-toxin producing maize than its isogenic counterpart. No such difference in food choice was observed in the case of the other two collembolan species. *S. coeca* showed neither avoidance nor food preference. The results of the food preference tests were not influenced by the number of animals per arena. In contrary to the animals in normal feeding status, starved *F. candida* specimens consumed more food even from Bt-maize.

These results may give some insight into the reason for feeding activity of soil animals in Bt-toxin containing soil being lower than that in the control soil. Our results show that the effect of residues from the Bt-toxin producing maize depends on the collembolan species involved in the test. Some collembolan species tends to avoid, while the other disprefers the Bt-toxin producing maize. The above detected phenomena may lead to an altered maize residue decomposition rate.

Biodiversity of the macrofauna in a fragmented landscape four land use from Santa Marta in Los Tuxtlas Ver. Mexico

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In the frame of the project Conservation and sustainable management of below ground biodiversity (GEF, UNEP, TSBF-CIAT) an inventory of the soil macrofauna was carried out in three windows around the volcano Santa Marta in los Tuxtlas Veracruz. In each windows 4 land uses were identified: forest, agroforestry, pasture and maize. Per window 8 points in each land use were sampled, all the points were at least separated from 150 m. In each point one monolith 25x25x30 cm was carefully manually revised, beside 2 other monoliths 50x50x10cm were quickly revised in order to collect the larger organisms. The earthworms were preserved in formaldehyde at 4% and the other organisms in alcohol at 70%. At this moment we are identifying the different taxonomic group, we are counting and weighting to obtain their density and biomass m⁻². We expect to have a more diverse and less exotic macrofauna in the forest and agroforestry land use than in the pasture and the maize field. These data will be correlated with the soil physicochemical factors.

Analysis of earthworm behaviour: putting ecological types to the test

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It is often claimed that by their foraging activity, the different ecological types of earthworms (particularly anecic and endogeic species) would get rise to differentiated structures in the soil. These different structures are thought to have different influences modifying physical, chemical and biological properties of soils. But until now, this postulated relationship between ecological types, burrow systems structure and influence in the soil was not really assessed due to technical difficulty to study the earthworm behaviours and their burrow systems.

To confirm or infirm the usual classification of earthworm in ecological types, this work used a new tool, the “colonne gamma”. It enabled to track the movements of radio-labelled earthworms in repacked soil cores (25 cm in diameter; 40 cm in height). 3D trajectories was tracked and analysed for individuals of three anecic species (*L. terrestris*, *N. giardi* and *N. nocturnus*) and two endogeic species (*O. lacteum* and *A. icterica*). The earthworm movements were split in three kinds of activity (“burrowing”, “displacement” and “inactivity”) and the respective lengths and times of movements was measured.

If the agreement between the observed and the predicted behaviour was good for *L. terrestris* which created only one vertical burrow and frequently reused it by oscillatory displacement, on the contrary, the behaviour of *N. giardi* and *N. nocturnus* and their burrow system morphologies did not correspond with the predicted by the ecological type theory. Indeed *N. giardi* and *N. nocturnus* created complex burrow systems and reused them for a part only. For a minor degree *A. icterica* and *O. lacteum* displayed the typical anecic behaviour like burrow ramifications and reuse of burrow systems. These observations could be a basis for a redefinition of ecological types, as far as behaviour is concerned. Indeed it would be possible to define a new ecological type called “endo-anecic” corresponding to the behaviour of *N. giardi* and *N. nocturnus*. The determinism of the behaviour of the endo-anecic could be analysed with the “colonne gamma” by controlling or monitoring environmental gradient (water, temperature) inside soil cores.

Quantification of earthworm behaviours could be a suitable way to earthworm inoculation for soil rehabilitation of groups of earthworms recognized as making complementary roles in soils.

Keywords : Earthworm ; Ecological Types ; Behaviour ; Burrow System ; 3D Tracking

Soil nematofauna structure, indicator in environmental monitoring: development of a molecular tool

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Nematodes are the most abundant and diverse metazoans on earth. Soil nematodes include organisms which occupy various positions in the soil food web: micropredators (bacterial-feeders and fungal-feeders), predators, plant-feeders and omnivores. They vary in sensitivity to pollutants and environmental disturbances. The collection of characteristics of these organisms makes soil nematode community structure a relevant bio-indicator for the study of environmental changes and particularly changes in environment use.

The impact of the changes of pasture intensity was addressed by studying a set of parameters concerning soil, vegetation and soil organisms over 3 years. The structure of the nematofauna was studied classically by morphological analysis and identification of a large number of nematodes extracted from the studied soil samples. Simultaneously, a molecular tool was developed in order to rely less on expertise in taxonomy and make these analyses accessible for more studies.

Nematodes 18S ribosomal DNA were amplified and sequenced for most of the species found in the studied agro-ecosystem. Then the structure of the nematofauna was characterized by genetic fingerprint, PCR - SSCP. The coupling of two techniques, morphological and molecular analyses, was done in order to develop an easier and more relevant method of analysis of the nematofauna.

Soil macrofauna in no-tillage systems with cover plants in Brazil (Goias State). Comparison with natural ecosystems and conventional agrosystems

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Since the early seventies, no-tillage systems with cover plants, defined as conservation systems, have been widely extended in Brazil, and nowadays, they occupy more than 18 millions ha. These practices have been recently more specifically developed in the Cerrado and Amazonian region on lands that were generally occupied by natural ecosystems (tropical forest, savannah - Cerrado).

The absence of tillage and fragmentation in the upper soil horizons allows for the accumulation of crop residues at the soil surface and the formation of mulch. Recently some studies have shown the importance of such systems for both the improvement of soil physical properties and carbon storage. Nevertheless only few studies have focused on biological properties and especially on macrofauna. However, the use of cover plant, the presence of mulch and the absence of soil tillage are likely to stimulate the development of soil biota.

In the present study, soil macro-invertebrates were sampled in two sites of the Goias State, Central Brazil (Santa Helena de Goias and Rio Verde). The soil of both sites is a red clayey latosol. Soil macrofauna was sampled during the rainy season (April 2000 and 2003 at Santa Helena, January 2004 at Rio Verde).

In each site, soil macrofauna was sampled (i) in natural ecosystems (cerrado), (ii) in conventional-tillage agrosystems, and (iii) in various no-tillage agrosystems differing by their age (after conventional tillage).

Results show that macrofauna densities and biomasses were very low in conventional systems: less than 400 ind m⁻² and 2 g m⁻², respectively, at Santa Helena de Goias. Earthworms were very rare whereas ants and coleopteran larvae presented the highest densities and biomasses, respectively. In comparison, no-tillage systems presented much higher densities and biomasses. This was observed even in the 1 year-old no-tillage crops: 2500 ind m⁻² and 45 g m⁻², respectively. Earthworm density reached 400 ind m⁻². A result was that surprisingly, no-tillage systems older than 1 year did not present densities and biomasses higher than these observed in 1 year-old systems. Once the tillage has stopped, and the cover plants are installed, soil fauna rapidly recolonizes the soil and reaches maximal values.

Thus, no-tillage systems with cover plants present much higher macrofauna densities and biomasses than these observed in conventional-tillage systems, which could explain the modifications of soil physical properties and organic matter dynamics observed in these systems.

Long-term effect of a legume cover crop (*Mucuna pruriens* var. *utilis*) on the communities of soil macrofauna and nematofauna, under maize cultivation, in southern Benin

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In southern Benin, as in other tropical areas, natural fallows, which were traditionally used to improve soil fertility, are no longer possible in a context of high population pressure, where the density of the human population reaches 400 inhabitants km⁻². To ensure the sustainability of plant production, many studies have demonstrated the advantages of legume cover crops. These can increase soil organic matter content, increase the production of maize grains, improve the water regime of soils, and reduce runoff and erosion. The mechanisms responsible for these effects are, however, not completely understood. The characterization of biological activity and diversity in a soil can help in understanding the dynamics of soil structure and the flux of nutrients. To this end, microbial biomass and the density, diversity and functional composition of soil nematodes and soil macroinvertebrates were measured in different treatments under maize cultivation in southern Benin. The treatments were (i) a pure traditional maize crop without any fertilization (T), (ii) a maize crop with a mineral fertiliser (NPK) and (iii) a maize crop inter-cropped with the legume, *Mucuna pruriens* var. *utilis* (M). Soil in plot M presented different biological properties when compared with T and NPK: higher macrofauna density (especially termites, earthworms, millipedes, centipedes), and biomass (especially earthworms and termites), higher density of facultative phytophagous, bacterial-feeding and predatory nematodes, and lower density of obligatory phytophagous nematodes (*Criconemella*, *Scutellonema* and *Meloidogyne*). The modification of the composition and activity of soil biota under *Mucuna* might explain the potential of *Mucuna* for soil restoration.

Soil macroinvertebrate populations in various land management systems in Paraná State, Brazil

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The soil macrofauna, i.e., organisms easily visible that live in the soil or on its surface for at least some part of their life cycle, includes invertebrates considered both as pests and/or as beneficial to the soil environment and plant production. Ants, termites, earthworms, beetles, grubs, pill-bugs, true bugs, cicadas, snails, millipedes, centipedes, crickets, wasps, spiders and various insect (especially moth and fly) larvae all form part of the soil macrofauna community. They include saprophagous organisms that act as decomposers and mineralizers, root and shoot-feeding organisms that negatively affect plant growth, predators and necrophages that feed on other organisms, geophagous bio-turbators that burrow through the soil leaving their excrements on or under its surface, social insects that create nests and congregate in large numbers, and omnivorous organisms, that feed on many different substrates.

The aim of the present study was to assess the soil macrofauna communities in different land management systems and native Atlantic forest in the region of Londrina, Brazil, focusing on the community composition and the abundance of the various groups comprising the macrofauna community. This would then help identify the key organisms present, that would be further studied, to test for their functional significance in the agroecosystem (e.g., pest or ecosystem engineering effects). Samples were taken in the summer crop (soybean) and after winter wheat harvest, in plots with 8, 13 and 20 years of conventional planting (CT: disk plow), chisel plow (MT) and no tillage (NT), planted with continuous double crops (wheat/soybean) or crop rotation (lupine/maize-oats/soybean-wheat/soybean). Both in the summer (soybean) and winter season, under NT and MT a larger number of geophagous (earthworms), saprophagous (millipedes, termites), predatory (spiders, diplura, pseudoscorpions and centipedes) and some pest (moth larvae) organisms was higher than in CT, where a larger number of enchytraeids (saprophages) and beetles (some pests) were observed. In the winter season, a much higher number of ants was observed under NT and MT versus CT, and in general, a higher total number of macrofauna was found in the former systems compared with CT. In the summer season, the differences in abundance between management systems was mostly due to a lower number in MT versus CT and NT. Total abundance in the agroecosystems in both seasons ranged between 1000 and 2000 individuals m⁻². On the other hand, in the native forests, macrofauna abundance was much higher than in the agroecosystems. In the winter >3000 and in the summer, >11,000 individuals per m² were observed, with predominance of ants and termites.

The use of no-tillage as opposed to conventional tillage practices, especially when combined with crop rotations and cover crops, can enhance soil macrofauna populations and their contribution to soil function, leading to a more balanced community composition. The present results highlight the importance of agroecosystem management practices on soil macroinvertebrate communities and the role of adequate decision-making, in achieving a more balanced soil fauna community composition, thus enhancing its potential benefits to soil fertility, crop production and sustainability.

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Soil invertebrate communities in stressed European ecosystems

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Intensive landuse in Europe results in continual physical and chemical changes to land and soil. Soil invertebrates can be used for development of single- and multi-species test-systems for soil quality assessments under anthropogeneous stress. The research was performed in 18 terrestrial ecosystems stressed by common anthropogeneous impacts: recreation pressure, motorway or industrial pollution in Central Russia, Belgium and the Netherlands in 1983-2001. All three types of human stresses (recreation, motorway and industrial) induced similar changes in macroarthropods and microarthropods communities. In stressed microarthropod communities the decrease of abundance of non-specialised predators, chewing phytophagans, saprophagans and increase of abundance of rhyzophagans, sucking phytophagans and specialised predators was observed. All types of stresses increased or stabilised species diversity in macro- (in carabid beetles communities mainly increase of *Harpalus* and *Amara* species number, in weevils - *Sitonia* species number etc) and microarthropods (e.g. Mesostigmata mite species) communities. In stressed ecosystems sucking phytophagans have selective advantage as compared to chewing phytophagans, endoparasitoids as compared to ectoparasitoids, specialised predators as compared to non-specialised predators, etc., meaning that the feeding strategy play an important regulatory role in the community. Saprophagans and phytophagans, consuming chemicals, e.g. heavy metals in large quantities, are in general highly sensitive groups. The most sensitive groups belonged to first and second order consumers. In putative trophic chains in roadside ecosystems, non-specialised zoophagans (predators) contained less copper and zinc, than specialised zoophagans and parasitoids. When compared to the peculiarities of distribution of pesticides (e.g. DDT) and radionuclides (Sr90 and Cs137) it happens that in terrestrial ecosystems heavy metals were primarily accumulated (1) in soil invertebrates but not in vertebrates and (2) in terrestrial food-webs of soil invertebrates - in first order consumers - phytophagans and saprophagans. The tolerance of soil invertebrates communities to heavy metals as determined by universal mechanisms active on community (trophic structure, species diversity etc.), population (abundance, mass and sex structure of population) and organism levels of organisation is discussed.

Population and behavioural level responses of arable soil earthworms to paper fibre application

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A growing interest exists to recycle paper industry waste through arable soils. This study was partly motivated by reports of positive impacts of such on earthworm populations. The response of earthworms to soil application of cardboard industry waste fibre (0-fibre) was quantified in field and laboratory experiments.

A field experiment examined the influence of applying 6x10⁴ tonnes ha⁻¹ of 0-fibre to a silty-clay soil against no application. After two years earthworm densities and biomasses were estimated in stubble cultivated soil treatments. In addition, a comparison was made of *Lumbricus terrestris* L. midden density in direct drilled treatments.

In the laboratory, habitat choice tests were undertaken with two species from the field site, *Aporrectodea caliginosa* Sav. and *L. terrestris*. Three litre pots were used, half of each filled with soil and the other half with either soil mixed with 0-fibre or 0-fibre and chicken manure, using field application rates. Six mature *A. caliginosa* were placed centrally on the surface and left to burrow. A perforated lid was attached and pots kept in darkness at 16°C for 3 days. A dividing plate was inserted and number of animals in each half recorded. Number of replicates was 20 per soil-treatment pair. *L. terrestris* was similarly tested (3 individuals per pot, 8 replicates).

As *L. terrestris* is a surface-feeding earthworm, its preference for 0-fibre and 0-fibre amended with chicken manure were compared with chopped barley straw in an additional setting. Individuals were housed in 0.5 m soil-filled tubes (diam. 0.1 m). The three feeds were presented in dual choice tests, as semi-circular arcs upon 0.25 m² soil surface around the worm's burrow. Foraging behaviour was observed using infrared video recording of four individuals simultaneously. Masses of different materials collected over 7 consecutive nights was recorded, in addition to time spent foraging on the food types. Seven replicated sessions with different animals were used.

Field results showed 1.7 times greater total density of earthworms in plots where 0-fibre was not added ($p < 0.05$) while the difference in fresh weight between treatment and control was not statistically significant. There was an indication of higher average number of *L. terrestris* middens when 0-fibre was not added ($p = 0.07$).

In the laboratory *A. caliginosa* showed no discernible preference between soil, and soil mixed with 0-fibre, but favoured soil compared with soil mixed with 0-fibre and chicken manure ($p < 0.001$). Also *L. terrestris* avoided soil with 0-fibre mixed with chicken manure ($p = 0.03$). The differences in foraging time of *L. terrestris* for the materials were not well established by the data, but mass of straw collected was greater compared with either type of 0-fibre treatment ($p < 0.07$).

In our experiments we found no indications for positive responses of earthworms to the 0-fibre products. Rather the opposite was the case both at the population and behavioural level. However, the negative impacts observed in the field may have been due more to indirect negative effects (e.g. relating to N-immobilisation in 0-fibre treated soil) than any direct harmful impacts of the 0-fibre application.

Long-term land use effects on soil invertebrate communities in southern Appalachian Piedmont soils

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Historically, a large percentage of land area in the Piedmont of the southern USA was under intensive agricultural management for the production of cotton. This intensive farming resulted in massive losses of topsoil, and general degradation of soil resources in the region until insect pests and poor economic conditions forced large-scale abandonment of farmland around the 1930's. In subsequent decades, there have been four predominant land-use trajectories in the region including 1) continued row-crop cultivation, 2) conversion to grass for pasture or hay production, 3) establishment of loblolly or shortleaf pine plantations, and 4) maintenance or regeneration of the native oak and hickory hardwood forests. The objective of this study was to examine the soil invertebrate community composition in relation to these long-term land uses. We sampled soil macroinvertebrates from 3 replicates each of cultivated fields, pastures, loblolly pine stands, and remnant hardwood stands for a period of two years. At each site we dug 3 or 4 soil pits that were 30 x 30 cm to a depth of 15cm, and sorted the soil volume by hand for a period of not more than 1 hour, collecting all invertebrates ~5 mm in length or longer. We collected abundance and biomass data for all invertebrate taxa collected, and we also calculated community indices including diversity, richness, evenness and percent similarity in order to identify patterns of community assemblage within each land use type. Preliminary results from this work suggest that soils in the remnant hardwood stands support the most taxonomically diverse macroinvertebrate communities followed by pine stands, pastures, and cultivated fields in order of decreasing diversity. Earthworms native to North American soils, *Diplocardia* spp. and *Bimastos* spp. were most abundant in the hardwood stands, but sometimes made up a substantial fraction of the earthworm community in cultivated soils; whereas introduced earthworms (primarily *Apporectodea trapezoides*) were most abundant in the cultivated and pasture soils. Scarab beetle larvae were present in all four systems, but reached high densities only at the cultivated or grass sites (e.g. mean density of 46 ind. m⁻², on one sample date in cultivated soils). Carabid beetle larvae were almost always collected only from cultivated soils. Several taxa were collected either exclusively or predominantly from hardwood sites, including diplopods, chilopods and gastropods. These results indicate that relative levels of long-term soil disturbance and the attendant differences in vegetation structure have profoundly influenced the community composition of invertebrates in Southern Appalachian Piedmont soils, and that more intense disturbance results in a less diverse invertebrate community composed of a few, frequently non-native, disturbance tolerant species.

Grassland related epiedaphic fauna as possible ecological indicator for environmental evaluation of different types of organic and mineral fertilizers application

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There is already much research about the effects of the use of different sources of organic and mineral fertilizers on the physical-chemical properties of the soil, but less is known about their effects on the epiedaphic fauna. The primary aim of this essay is to compare the effects caused by different fertilization strategies on soil system based on the application of: i) dairy sludge, ii) cattle slurry, iii) poultry dung and iv) chemical fertilizers; both in terms of their suitability to the nutrition of crops and their environmental influence. The four types of fertilization are compared among themselves and with non-fertilized plots of grassland. The research work consisted of the installation, in October 2001, of an experiment in casual blocks where a pasture of rye-grass and white clover was sown. The experimental units are composed of 20 plots with 3m x 1,3 m where five fertilizing treatments were established at random with four repetitions. From time to time, we followed the most important parameters in terms of soil and cultures, in the way they affect the fertility of the soil (fertilizing power) and the environmental quality (diversity of invertebrates). "Pit fall" traps were employed to invertebrates recollection. Abundance distribution curves, Margalef, Shannon and Simpson diversity indices were also used to analysing possible differences on epiedaphic communities. The application of organic and mineral fertilizers promoted in the same way the chemical fertility of the soil and the fodder production. In 2003, the fertilization with poultry dung (BioF) surpasses the other treatments in most chemical characteristics of the soil. The results derived from the use of measures of diversity didn't allow to identify significant differences concerning the distinct treatments. The fact that we are in an agricultural environment with communities, poor in diversity both in relation to the number of families and in relation to the number of individuals that represent each family is which has influenced the results most. However, we checked that the BioF promotes the activity of the epiedaphic fauna better than the other treatments we have used. The best chemical characteristics of the soil favoured by the BioF application could explain the greatest richness and dominance of the families of the plots undergoing this treatment.

Effects of Bt maize on soil organisms: results of a two year study on three European sites

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Cropping systems using Bt maize MON 810 were compared with Conventional systems using the corresponding isogenic variety of maize. The main objective was to study the global effect of GM crops on the soil environment, including other farming practice changes that could occur following the introduction of Bt maize. For that purpose, soil organisms and soil functioning were assessed on three European sites situated in Jutland (Denmark), Bourgogne (France) and Midi-Pyrénées (France).

Sampling occurred on each site, twice a year, just after seedling and during the harvesting period. Microbial community structure was studied using PLFA and substrate utilization profiles using the BIOLOG® method. Numbers of protozoa (amoebae, ciliates and flagellates) were estimated from most-probable-number calculations. Nematodes were extracted using the Baermann funnel apparatus, counted under a dissecting microscope and identified at the family level. Microarthropods were extracted from soil cores, using Berlese or MacFadyen method, and identified at the sub-order level for mites or at the species level for springtails. Enchytraeids were extracted by flotation in water and then counted under a binocular microscope. Earthworms were sampled by hand sorting of soil cores, counted, weighted and identified at the species level. Wheat straw decomposition was determined using a litter-bag technique.

The largest differences observed were between sites, between sampling period (spring and autumn) and between plots sown with maize (either Bt or non-Bt) and plots sown with grass. Nematodes, for example, showed an overall reduction from 26 nematodes g⁻¹ under conventional maize to 20 g⁻¹ under Bt-maize when averaged across all three sites, but there was no differential effect on the composition of the nematode community. This may be an indirect effect related to the observation that the soil at sampling was drier under Bt-maize than conventional maize. The results will be presented in detail and discussed in relation to the soil food web.

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Grassland management practices and the diversity of soil nematode communities

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At the upland field site of the Natural Environment Research Council's Soil Biodiversity programme, plots of an established *Festuca - Agrostis* pasture and of a newly sown monoculture of *Lolium perenne* have been treated for 3 years with nitrogen and lime or with pesticide (chlorpyrifos). These treatments were designed to produce contrasting degrees of diversity in communities of soil animals and microbes as part of our research on the relationships between grassland management practice and the diversity and functions of soil biological communities. This talk will describe the responses of nematode communities and their relationships to root growth and microbial community structure and activity over three years. In ryegrass monoculture plots numbers of nematodes declined at all samplings. This treatment had no impact on numbers of plant parasitic nematodes but there were fewer plant/hyphal feeders and more fungal and bacterial feeders in the reseeded plots. In the second year there were more predatory nematodes in these plots. Nitrogen and lime application reduced nematode numbers significantly, having little impact on plant feeders, but decreasing numbers of plant/hyphal and fungal feeders. These fertilised plots had increased proportions of bacterial feeders, with an associated increase in predators. In additional plots, the ¹³C fixed by photosynthesis of a 24h pulse of ¹³CO₂ applied to the herbage, was detected in nematodes extracted from underlying soil at 8, 22, 48 and 69 days after the pulse. There was more ¹³C in nematodes from untreated controls than from limed plots. These differences are consistent with a greater carbon flux in soils treated with lime, but could not be related to differences between the nematode communities.

Is *Dichogaster bolau* the first domicole earthworm species?

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Domicole species (species adapted to living in urban dwellings) are common, for example, among Psocoptera (dust lice) and spiders. In earthworms, there has not been any species known to adapt to this kind of niche. However, it seems that the tropical species, *Dichogaster bolau*, might be the first one. The species is widely distributed in tropical and subtropical regions, and has been often recorded in greenhouse soil in temperate countries. In Sweden and Finland it was also observed in bathtubs and toilet bowls.

We collected additional data about the abundant presence of this species in bathtubs and showers in Hungary and Israel. It seems that this species adapts independently to living in and/or around the water pipes connected with bathtubs and showers, i.e., it becomes domicole. Probably, these water pipes allow this tropical species to survive in otherwise climatically hostile conditions, especially during winter. It should be noted, that there are no records of the outdoor presence of this species in temperate countries.

Long-term establishment of earthworms in reclaimed cutover peat soils in Ireland

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Significant levels of earthworm colonization were recorded within 5-6 years of grassland establishment on peat soils reclaimed for agriculture following industrial peat extraction in Ireland (Curry and Boyle, 1995). Data will be presented on current earthworm distribution, diversity and abundance in these sites, 20-25 years following reclamation and grassland establishment.

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Recovery of earthworm populations following depletion by intensive cultivation

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The response of earthworm populations to different cultivation and cropping regimes has been studied in two adjacent 1 ha field plots on the U.C.D. research farm at Lyons Estate, Co. Kildare, Ireland since 1994 (Schmidt and Curry, 2001; Curry et al., 2002). Earthworm populations declined drastically following intensive cultivation for potato production in 1998 and remained at barely detectable levels under Spring barley crops in 1999 and 2000. Only three species were recorded from the area in September 2000; the mean population density was 22 ± 6 individuals m^{-2} and the mean biomass was 4.7 ± 3.8 g m^{-2} at that time. The area was sown to ryegrass (*Lolium perenne*) in Spring 2001 and no further cultivation was carried out until September 2003 when the ley was broken for winter wheat.

By May 2003 the population had partially recovered, especially in the plot which had formerly been under wheat with a clover understorey. Seven species were present, the mean population density being 32 ± 4 ind. m^{-2} in the plot which had been under conventional wheat and 101 ± 14 ind. m^{-2} in the plot which had been under wheat + clover in 1995-1997. The corresponding values for biomass were 11.2 ± 1.2 and 45.2 ± 9.6 gm⁻², respectively. Thus, while the 2.5 - year ley break permitted some population recovery, it was not sufficiently long to allow full restoration of the population levels which were present prior to intensive cultivation for potatoes in 1998.

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Discovering the most important agricultural factors for soil microarthropods using machine learning methods

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In agricultural soil a suite of anthropogenic events shapes the ecosystem processes and populations. The risk of impact from anthropogenic sources on the soil environment is almost exclusively assessed for chemicals only, although in agriculture other factors like crop and tillage have large impacts too. As farming systems consist of a combination of a certain temporal sequence of events of different type and duration this is the ultimate risk imposing complex “unit” to the non-target soil ecosystem. Thus, the farming system as a whole should be evaluated and ranked in order of its environmental benefits and impacts. One way to do this ranking is to collect information about the agricultural events and the soil biological parameters reflecting those events and relate the sequence of agricultural events to the biological parameters. Our starting point was the availability of (our own) such data set and some, now classic machine learning methods, used to identify and quantify the relationship between one variable and a set of descriptors. Our aim was to make attempt in presenting empirically based models useful for predicting the soil quality in terms of quantities describing the soil microarthropod community from agricultural measures. A further prerequisite was that we wanted to discover additional knowledge on a higher level and identify the most important factors for the species that are deemed as indicators of good soil and so discover which agricultural actions are beneficial to the soil quality and which are not. Using methods of model tree discovery and regression tree discovery we modelled the population densities of mites and springtails and their biodiversity. We also produced models for some of the individual species of springtails and mites that are usually found in good soil and can be used as indicators of good soil. While the models that are good predictors can be quite big and complex (and hard to understand) we had to keep the models smaller and simpler (while limiting the performance loss) to discover which factors have the greatest impact on microarthropods. From those smaller models we found out (and confirmed the experts anticipation) that the microarthropod communities and single species are mostly dependant on crops planted in the history of the field (as long as tree years ago) and on the tillage in previous months (as long as six months ago).

Evaluation of the environmental impact of pesticides on earthworms in apple orchards

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This study aimed at determining possible markers of the environmental impacts of pesticides in apple orchards in Provence using earthworm as a model organism. Our experimental design was a set of 18 orchards: 5 in conventional farming, 5 in IPM (Integrated Pest Management), 5 in organic farming and 3 abandoned (since at least 5 years) orchards as a control. This study was done at different biological level going from earthworm communities (diversity, biomass and different indices) to single organism (using two biomarkers: cholinesterases activity and genotoxicity on coelomocytes).

At the community level, earthworm biomass was significantly higher in organic farming due to high densities in *Lumbricus terrestris* in these orchards. Multivariate analyses were then carried out to separate effects of soil characteristics and effects of farming practices (pesticides).

The specific activity of cholinesterases of *Allolobophora chlorotica* was significantly inhibited in all conventional farming and half of the IPM orchards. This inhibition was observed in spring and summer and disappeared in winter. This is the first time this biomarker is validated under natural conditions on earthworms.

Genotoxicity test on coelomocytes was first validated in vitro. We were then able to show a positive response in two orchards (one in conventional and one in organic farming). This response could be due to a limited number of pesticides (such as captane) whereas response for cholinesterase is clearly due to organophosphate insecticides that are currently used in apple orchards (except in organic farming). This study illustrates the necessity to take into account response coming from different markers in field studies.

Soil macrofauna response to soil, habitat and landscape features of land use intensification: an european gradient study.

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Land use change is one of the major cause of biodiversity decline. Proven role of soil fauna soil functioning is widely accepted. Impact of land use change on soil fauna at plot level is well documented. Relatively few information exists on the effects of land use intensification at landscape level on soil macrofauna. Determine habitat and landscape feature leading biodiversity patterns is an essential step in the assessment of the impact of land use intensification.

One of the purpose of the European project BioAssess was to standardized protocols to measure biodiversity and to quantify the impact on biodiversity of land use change. Macrofauna diversity was studied along land-use gradients in eight European countries.

Collection and identification of soil macrofauna from a total of 768 0.25m³ samples of soil revealed 17 orders, 131 families and 908 species. Two-thirds of the soil macrofauna was composed of singletons or doubletons. As the correlations between species number and family number were significant for all soil macrofauna orders except for ants and Lumbricidae, the family level appeared to be the most relevant unit to consider as a biodiversity assessment tool for soil macrofauna diversity. Mean family richness did not vary significantly across the land use gradient.

A distribution model of soil macrofauna is related to influencing factors by means of multivariate statistics (canonical correspondence analysis (CCA), partial CCA). Hypothetical influencing factors are categorised as follows: 1) soil characteristics (pH, humus, texture, organic mater depth, slope), 2) habitat (habitat type, management type, plant species richness) and 3) landscape (habitat heterogeneity, variability, diversity, proportion of natural and semi-natural areas).

The correlative model developed for the soil macrofauna assemblages in the French study case revealed that the three consider levels of ecosystem organisation influenced the soil macrofauna pattern (18.6% of the total variance explained). The most important was those related to soil and to habitat type and habitat management: respectively 4.2%, 5% and 4% of the total variance explained. Percentage of forest area has the major influence at landscape level : 2.3% of the total variance explained. This model shows that the most important local habitat factors are those directly influenced by management practices.

The comparison of the models develop for each study site seem showed that the local factors and specially those related to management practices are those the most influencing.

Post agricultural responses of beetles in the Mediterranean dry grassland of the plain of la Crau (Bouches-du-Rhône, France)

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Current concerns in conservation biology and restoration ecology make dry grassland ecosystems a key biological model for the study of human disturbance impacts. Cereal and melon farming, between 1965 and 1985, was very destructive for dry grasslands or "coussou" in the plain of la Crau (southern France). Over a twenty-year period, three formerly cultivated plots developed new fallow-land floristic structures, where species richness was less than that of "coussou". They also differed according to their past agricultural practices and time since abandonment. In order to understand the response of Coleoptera communities to these floristic changes, several trapping campaigns were undertaken between April and October 2002. Non-attractive glycol traps were buried flush with the soil surface in the center part of the three fallow-lands and the coussou. A total of 3290 Coleoptera, representing 147 species, were collected. These results were subjected to various statistical analyses (simple linear regressions, similarity and diversity indices, COA, RDA...). Results demonstrated that fallow-lands have greater entomological richness than the "coussou". The poor nutritive interest of *Brachypodium retusum*, which is the dominant plant of the "coussou", could explain these results. The typically ruderal fallow-lands vegetation appears to be an interesting alternative food resource for beetles and could explain this high species richness. However, the coussou supported species of great interest that increased the ecological value of this ecosystem. The opposition between vegetation and Coleoptera responses highlighted the importance of multi-level studies of disturbance effects.

Effect of the habitat fragmentation in Kis-Balaton Natural Conservation Area, Hungary

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During the reconstruction of Kis-Balaton area the former contiguous land was fragmented into separate areas. Our aim was to reveal the resulting changes in the community structure of certain living organisms (testaceans, enchytraids, collembolans, small mammals). The investigated sites covered three orders of magnitude: Small (10-100 m²), medium (300-500 m²) and large (1400 m² – 4 ha) islands were sampled, comprising diverse habitat types. We encountered differences in the community structure at only two of the four examined groups of organisms: In testate amoebae both size and position of the land fragments affected the number of species and individual abundance. In enchytraeids and collembolans there was no correlation between the size of the fragments and species richness. In the small mammals populations marked differences occurred among the sites regarding diversity as well as density, here detecting the fragmentation was hampered by rapid plant degradation, typical all over Kis-Balaton area. Species lists resulted new species for science (enchytraeids) and the Hungarian fauna (testaceans).

We concluded that the observed differences in the studied community structures could have been assigned to the habitat fragmentation caused by the gradual inundation of the area. Generally, large, mosaic-like wet habitats were inhabited by the richest fauna, since different microhabitats were connected to each other, promoting animal migration. Small and medium sized land fragments harboured poorer and more vulnerable populations.

Ecofaunistical investigation of Testacea, Oligochaeta, Collembola along the bank of Tisza river, Hungary after the cyanide pollution in 2000

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During 2000 two, significant pollution waves came from Romania and went along the Tisza caused tremendous damages in the ecosystem of the Tisza valley. There was cyanide pollution at the end of January and heavy metal pollution in March. Our aim was to demonstrate the effect of cyanide (and heavy metal) pollution on different groups of organisms, which differ from each other in size, ability of mobility and in claim of ecological circumstances. We investigated the fauna of Testacea, Oligochaeta (Enchytraeidae, Lumbricidae), Collembola. We collected samples from July 2000 till July 2002 at least one time in every season. The animals were collected from the selected sampling sites (contaminated and uncontaminated parts of the river bank) different special methods depending on the type of organisms. We compared the community structures of the investigated animals in the different habitats of the sampling sites.

We concluded that the observed differences in the studied community structure could not have been proved the effect of cyanide pollution. But we found relationships between the structures of communities and the structures of different habitats. The diversity and density of the investigated organisms depend mainly on the type of the habitats, on the microclimatic characters, not on the locality. The species lists resulted two new species for Hungarian fauna and four new species for science have been described.

Temporal effect on earthworm population structure resulting from change in agronomic practices

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Long-term (established 1983) no-tillage, conventional mouldboard plow tillage, ridge-tillage, and bluegrass sod treatments on a heavy clay loam were split the fall of 1996 and half of the conventional treatment was converted to no-till, while half of the ridge-till, no-till, and sod treatment was converted to conventional tillage. The tillage treatments were replicated twice; crop rotation is corn-soybean. The converted agronomic practices together with the original treatments have provided the opportunity since 1997 to follow the temporal effect on earthworm population structure. Converting agronomic practices introduced major changes to the soil system with respect to quantities and distribution of crop residue cover and the extent of soil disturbance received from tillage implements. Earthworm populations are known to be sensitive to these changes but the nature of their response with time is relatively unknown. Information concerning this response is important for decisions related to assessments of soil quality and whether earthworms are appropriate for use as indicators of soil quality. For each treatment, 3 replicate earthworm samples were taken in each of 1997-1999 using a 1% formalin solution in 7L, and since then, because of environmental concerns (2001 and 2003 samplings) hot mustard powder (paste of 50 grams in 7L water). The extractant was applied to an area of 60cm x 60 cm; and worms were placed in 70% alcohol. Earthworms were examined with respect to proportion of numbers present, and biomass. Two species dominated all treatments, that is, *Lumbricus terrestris* and *Aporrectodea turgida*. Environmental conditions varied from year to year with drought conditions, thereby affecting the numbers of earthworms that could be obtained with use of chemical extractants. A ratio assessment of the data in terms of newly converted practice to the long-term practice provided a means by which trends in population abundance could be compared between years. For 1997-99, 2001 (2003 data under preparation), converting from no-till (in 1983) to conventional till (in 1997) ratios for population abundance have ranged from 0.13 to 0.32, that is one to three tenths the number of earthworm are now present in the conventional tilled treatment than in the original no-till system. This decrease was immediate in the first year and has remained since then. With conversion of conventional till (in 1983) to no-till (in 1997), ratios for abundance have ranged from 2.5 to 5.3, that is 2 to 5 times more worms are now in the converted no-till system than are present in the original conventional treatment. This has been a fairly constant trend. Converting ridge-tillage to conventional tillage, population abundance ratios ranged from 0.41 to 0.62. Converting from bluegrass sod to conventional till, ratios varied from 0.93 to 3.8, that is, 1 to almost 4 times more earthworms in the conventional tilled treatment. This difference can be attributed to the drier conditions that prevail under the dense sod not being conducive to preferred habitat for burrowing worms. For biomass, similar trends were noted for the treatments. These results will be discussed in terms of potential for use as indicators of soil quality.

Temporal changes of fertility and macrofaunal communities in rehabilitated tropical open mined soils of southeastern Mexico

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By using soil clays and the bed rock for the elaboration of cement, open pit mines of the cement industry eliminates all the aboveground vegetation and the belowground biotic community. During the rehabilitation process an important step is the addition of soil, currently imported from other sites. These soils are totally unstructured and with a heterogeneous and often non functional macrofaunal component. Few studies have characterized the macrofaunal invertebrates in these rehabilitated soils and its change over time.

In this study we characterized and monitored temporal changes of soil fertility and macrofauna in sites rehabilitated by the Holcim-APASCO cement industry (Orizaba, southern Mexico). Four different rehabilitated sites were studied: Terraces in limestone 45° steps rehabilitated with grass (SG) and trees (ST) and flat mud banks rehabilitated with grass (FG) and trees (FT). Three other sites were used as controls: a mixed cloud-tropical forest (TF), a fallow (F) and a reforested fallow (RF). In each site soil macrofauna was extracted from 5 TSBF monoliths (25X25X30 cm, stratified in three layers of 10 cm depth) placed at intervals of 10 m along a 50 m transect. Analysis of organic matter and nitrogen were performed for each layer of each monolith. Sampling was performed in august 1995 and august 1998. In September 2000 an additional sampling was made only in ST.

In 1995, after two years of the beginning of the rehabilitation process, soil macrofauna of sites SG, ST and FT was low diverse and dominated by ants (68, 98 and 78% of abundance, respectively). Only in the FG site the community was diverse and equitable; it also was the only site with important earthworm biomass values (more than 80 g/m², representing 63% of total biomass vs. less than 3% in the other rehabilitated sites). Comparing with the control sites, all but FG where low diversity sites.

Three years later (1998), and five after the beginning of rehabilitation, forest sites (ST, FT) presented higher diversity and equitability than grass sites (SG, FG). The forest site in terraces (ST) presented the larger changes, with ants clearly decreasing its relative abundance and biomass. This was also the site with the best rehabilitation of aboveground vegetation. In terms of fertility ST and FG were the sites that in 1998 presented increases of organic matter and nitrogen contents.

We conclude that two factors enhanced the soil macrofauna community: i) Cattle pastures with high earthworm biomass values and ii) successful rehabilitation of aboveground vegetation with native and exotic fast growing plant species.

Patterns of soil macrofauna along an intensification gradient in coffee plantations of southern Mexico

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It has been recognized that coffee plantations can be managed under different agricultural practices, and that in some regions these practices can be ordered along an intensification gradient. With the aim to test the hypothesis that soil macrofauna (diversity, abundance and biomass) and agriculture intensification are negative related, we sampled in southern Mexico the macrofauna invertebrates of four different coffee systems. These systems corresponded to different degrees of intensification (from low to high): i) traditional polycultivation (coffee cultivation under secondary forest and fruit trees), ii) commercial polycultivation (coffee under fruit trees and specialized shadow trees), iii) shady mono-cultivation (coffee under specialized shadow trees) and iv) open mono-cultivation (coffee without shadow). The original cloud forest was set as the control system. Two replicates of each system and 5 TSBF monoliths (25x25x40 cm) per replicate were performed; the monoliths were placed at distances of 5 m along a linear transect.

The results showed that total number, abundance and biomass of groups did not varied between systems. Some groups however presented significantly differences between systems (earthworms, ants, beetles and isopods) and others even showed inverse correlations with intensification (spiders, diplurans and myriapods). Total abundance was dominated by ants, which in five sites accounted more than 40%; in terms of biomass earthworms dominated, accounting in seven sites more than 70% of total weight.

Coffee plantations turned to be adequate systems for the majority of macrofauna groups, independently of management. Constant coverage and high litter input could be the responsible factors behind these patterns.

The effect of soil fauna on soil microstructure, organic matter accumulation and microbial activity during soil formation in reclaimed and non reclaimed post mining sites

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Two chronosequences, each consisted of four post-mining sites (10 - 40 years old) located on alkaline clay, were studied near Sokolov, Czech Republic. The sites differed in litter quality (spontaneous succession and forest reclamation). Herbs only covered the youngest spontaneous site. Shrubs (*Salix caprea*) dominated at 20 years old site, while trees (*Populus tremuloides* and *Betula* spp.) covered 30 - 40 years old spontaneous sites. Reclaimed sites were covered by alder (*Alnus glutinosa* and *A. incana*) plantations. Abundance of soil macrofauna was higher at reclaimed sites than at non reclaimed sites of the same age, in particular in the youngest and intermediate stages of succession.

Thin soil sections indicated more intensive litter fragmentation and soil mixing at reclaimed sites. In intermediate succession stages, fermentation layer was formed by excrements of Diplopoda and Diptera larvae and was partly mixed into humus layer. At older sites, fermentation layer disappeared due to mixing activity of earthworms. Activity of macrofauna was less pronounced at spontaneous sites. This resulted in the accumulation of litter on soil surface and, in intermediate succession stages, in the formation of thick fermentation layer consisted mainly of litter fragments and millipede excrements. Intensive earthworm activity resulted in rapid formation of humus layer at the oldest spontaneous site. Humus layer thickness and the amount of accumulated soil organic matter (SOM) at 40 years old spontaneous plot were comparable with those at reclaimed sites.

Field microcosms, accessible or non accessible for soil macrofauna, exposed in intermediate succession stages indicated that soil macrofauna did not increase significantly the loss of C from the system but enhance the accumulation of carbon in mineral soil. Consequently, soil water holding capacity, microbial respiration and biomass were higher in macrofauna accessible treatment. This effect was more pronounced at reclaimed than spontaneous sites.

To elucidate the role of individual guilds of soil fauna, representatives of mesofauna only, mesofauna + litter feeding macroarthropods or mesofauna + *Lumbricus rubellus* earthworms were introduced into laboratory microcosms consisting of heap substrate and litter from reclaimed or spontaneous sites. Presence of macrofauna resulted in more intensive litter removal. Litter removal correlated with the accumulation of C in mineral layer at spontaneous sites but no such correlation was found at reclaimed sites. Considering both litter types, litter fragmenting macroarthropods supported carbon loss and higher actual microbial respiration, while soil mixing by *L. rubellus* supported higher potential respiration and carbon accumulation in mineral layer.

In conclusion, higher abundance of soil macrofauna resulted in rapid formation of humus layer at reclaimed sites in intermediate succession stages. Increased earthworm abundance at older spontaneous sites, however, resulted in rapid formation of humus layer, possibly because large amount of organic matter accumulated on the surface of spontaneous sites in intermediate succession stages and in differences in litter quality. The effect of litter and fauna on SOM accumulation and microbial activity recorded in microcosms was compared with the pattern of SOM accumulation and microflora development during succession of sites.

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Carabid beetles (Coleoptera: Carabidae), as indicators of biodiversity and generalist pest control agents in peach orchards

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A study on population diversity of Carabid beetles (Coleoptera: Carabidae) was conducted for two years in peach orchards in Gard, in the south-east of France. The plots were managed under two farming systems, one in conventional production and the other under certification in organic agriculture. The organic plot itself was subdivided according to two types of ground covers of the inter-rows. Monitoring of the populations by pitfall trapping shows that the plot in organic agriculture had higher abundance of Carabidae populations in terms of species and individuals, with a better equitability between the species. The presence of an inter-row made up of four floral species increases the number of potential generalist predator species of peach pests in orchards.

Ecotoxicological bioassay on ivermectin with the MI bioindicator system: changes in the structure of nematode communities of cattle dung

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Ivermectin is a broad spectrum endectocide used in veterinary parasitology for its efficiency against endo- and ectoparasitic Invertebrates. However, non-target soil- and dung-dwelling invertebrates living in pastures may be impacted by cattle treatment. The widely used « pour on » ivermectin treatment may potentially increase the level of exposure to ivermectin, especially *via* the licking behaviour of cattle. Deep frozen dung cattle was used as microcosm in order to observe the response of the associated fauna, eg, of the Nematode community to ivermectin treatment. Responses to an environmental stress (such as the presence of a xenobiotic) may change with functional group. Our experiment was led *in natura* with numerous replicates in a randomized complete block design.

The natural succession during the colonization process of previously defaunated habitats is related to the development of nematode communities, resulting in an increasing value of the Maturity Index, MI. This index provides on one hand a way to measure the duration and level of exposure to ivermectin, and on the other hand a possibility to discriminate between the effects of eutrophication and pollution. This correlation is based on quantitative data on the concentration of this xenobiotic in microcosms, and helps to assess the risks connected with its use.

Biodiversity of terrestrial isopods along a gradient of disturbance in Sabah, East Malaysia

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Connell's intermediate disturbance hypothesis predicts that the highest diversity is maintained at intermediate levels of disturbance. We have examined this hypothesis by observing differences in biodiversity of terrestrial isopods along a gradient of disturbance from two undisturbed primary tropical rainforest sites, a logged site, a mixed native fruit orchard and a commercial oil-palm plantation, in Sabah, East Malaysia.

We will describe a standardised protocol that we developed for the rapid assessment of isopod biodiversity on tropical forest floor sites and for measuring environmental variables to which we have related differences in species richness and relative abundance of the isopods.

Preliminary analyses suggest that the results do not support Connell's hypothesis because most species were found in the relatively undisturbed, primary forest sites, although the relative abundance of individual species was highest in the most disturbed environment. We suggest that this may be because particular species are well adapted to exploiting resources under the more 'r' selected conditions created by disturbance. In this paper we will present the results of describing new species found on these sites and further detailed analyses to test these tentative conclusions more thoroughly.

Possible reasons for why the observations do not conform with theoretical predictions will be discussed in the context of the continuing debate about the rate and extent to which commercially driven disturbance is altering the biodiversity of very complex and fragile tropical forest ecosystems.

Ants (Hymenoptera: Formicidae) diversity in agricultural ecosystems at Mezquital Valley, Hidalgo, Mexico

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There are continuous mechanical and chemical disturbances in agricultural ecosystems, producing changes on the native species populations. Therefore, it is important to assess the health of the agricultural ecosystem in order to guarantee the support of the soil, thus allowing extending the utilization of this resource.

The ants constitute an important part of the edaphic mesofauna and produce a significant effect on the soil, vegetation and faunal groups with which they interact, within a wide range of key ecological processes.

In Mexico mainly studies has been performed in tropical regions. The Mezquital Valley, in the center of Mexico, is an important area of agricultural production, despite its arid environment, through the introduction of irrigation systems. The water used for that purpose is wastewater from the Mexico Valley.

The climate is semidry with marked seasons of rain and drought.

In this work we studied the ant communities changes according with their seasonal variation and irrigation type (well water and wastewater) in the plots.

We select 5 plots located at the municipalities of Mixquiahuala de Juárez (3), and San Salvador (2). At Mixquiahuala (20° 13' 09 – 99° 12' 08" 2000 m asl) the samples were obtained from plots irrigated with wastewater and used by different time: Lateral Requena more than 80, High Requena 40 and Tumba with 7 years of irrigation.

At San Salvador (20° 17' 00"- 99° 00' 09". 1780 m asl) the samples were carried out at El Bondho, where the parcel is irrigated with water from wells and San Salvador, irrigated with wastewater. Both parcels have been cultivated for more than 80 years.

A total of 21 Pitfall traps by plot were placed, during 7 days in each plot from February to March (drought) and August (rain) of 2003.

A total of 1625 organisms were collected (477 under drought and 1148 under rain), corresponding to 16 genus (*Cardiocondyla*, *Crematogaster*, *Dorymyrmex*, *Forelius*, *Labidus*, *Leptothorax*, *Linepithema*, *Monomorium*, *Neivamyrmex*, *Nomamyrmex*, *Odontomachus*, *Paratrechina*, *Pheidole*, *Pogonomyrmex*, *Solenopsis*, *Tapinoma*). *Pheidole* (40.4%) and *Monomorium* (23.7%) were the most abundant.

The high diversity was observed during the rain season (14 species). *Linepithema* and *Crematogaster* were collected only dry season. The highest abundance and diversity was observed at El Bondho during rainy season. For dry high diversity was recorded at Tumba. *Monomorium* was found in all plots, while *Cardiocondyla* and *Tapinoma* were only found at El Bondho, and *Odontomachus* at Tumba.

The season had a significant effect in the community composition. The plots with low disturbances show more diversity and abundance, indicating that the quality of the water is a determining factor for the community structure.

The genus *Cardiocondyla*, *Tapinoma* and *Odontomachus* can be indicator of low disturbance levels. It was also observed that these studies provide us with information about the biodiversity in the agricultural ecosystems within semiarid regions and areas irrigated with wastewater.

**Diversity of soil biota under anthropogenic influence in Serra do Mar rainforests of the Mata Atlântica (Paraná, Brazil):
Project SOLOBIOMA**

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In this project we sample and analyse the diversity of selected soil organisms during regeneration from pastures to old growth forests in the “Serra do Mar Coastal Forest”, a vegetation formation of the Brazilian Atlantic rainforest which has developed on the Precambrian geological formation. Three replicates of four regeneration phases for two different soil types (cambisol vs. gleysol) and three replicates of natural forest which are only found on cambisol are studied, totalling 27 sampling sites.

Two sampling methods are used: quadrat based litter samples are extracted in Winkler bags and soil core samples are extracted in a Berlese apparatus. In a first phase ants, spiders and oligochaeta (earthworms and enchytraeids) will be identified to the (morfo-) species level and their species richness and assemblage structure analyzed.

Ants belong to the most abundant and species-rich soil macrofauna groups in Neotropical forest ecosystems, including predators, herbivores and decomposers. They are recognized as ecosystem engineers and good indicators, and standardized sampling protocols are already developed. Spiders are the most species-rich and abundant predator group on the ground and are often used as indicators. Earthworms are also important as ecosystem engineers and recognized as most important for the nutrient cycling and the soil fertility.

With the sampled fauna material and a first assessment of a set of soil variables like pH, C/N-ratio, soil moisture, temperature and soil texture we will test our assumption that site-specific species assemblages exist and can be used to define typical soil fauna communities for specific soils or habitats. This would be the first step in the development of a "regionally differentiated BBSK" concept (Soil Biological Site Classification) which on long terms should serve to assess the habitat function of the soil in secondary habitats and finally come to recommendations for the conservation and regeneration of the rainforests of the Mata Atlântica.

The project is supported by the program “Science and Technology for the Mata Atlantica” of the German Federal Ministry of Education and Research and the Brazilian National Council for Research CNPq, project IDs: BMBF/DLR: 01 LB 0201 and CNPq: 6900148/01-1; run duration: Jan 2003 – Dec. 2004. Project leader: Dr. Hubert Höfer, contact: hubert.hoefer@smnk.de

Comparative study of earthworm diversity, biomass and density on three different soil system uses in the Biosphere Reserve “Pantanos de Centla”, Tabasco, Mexico

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Pantanos de Centla, one of the most important biosphere reserve of Mexico, has an extension of 169 000 ha. It is composed of three municipalities: Centla, Jonuta and Macuspana. In this reserve human activity is well presented. Earthworms as soil engineers (Jones et al. 1994), has an important role in soils systems. To compare the biomass, density and diversity of earthworms in different soil systems uses was the principal objective of this study. Three cultures systems: Mango, Cacao and yard culture (cultivo de traspatio) were categorized as perturbed systems. One non perturbed system was represented by relicts of tropical rain forest vegetation. Earthworms were collected by hand-sorting TSBF method (Anderson & Ingram 1989) from 10 monticules of 25x25x30 cm randomly distributed at each soil system. Earthworms were weight, counted and identified *in situ*, except in mango's culture, where we found the highest diversity, so earthworms were transported in 4% formaldehyde. From each soil system soil was collected for organic matter, nitrogen, pH, bulk density and texture determination. We found the highest earthworm diversity in Mango's culture, represented mostly with individuos of the genera Glossoscolecidae and Dichogaster. The highest earthworm biomass (40 g.m²) was found on the yard culture.

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Response of soil micro- and mesofauna to diversity and quality of plant litter

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The abundance and functional structure of soil micro- (nematodes) and mesofauna (collembolans and mites) in relation to species diversity and nutrient content (C:N ratio) of plant litter were studied in a field experiment. Mesocosms of size 0.5 m × 0.5 m × 0.15 m filled with sandy-clay mixture were inserted in the soil on Arrhenatheretalia meadow. Eight containers (rings 100 cm² in diameter and 5 cm high, with steelon net (mesh size of 1mm) on the bottom were filled with 9 g dry wt. of litter and placed on the surface of each mesocosm. To enable fauna penetration of the litter, a row of holes 1cm in diameter were drilled in lateral side of the rings. A total of five plant litter (from above-ground parts of plants) combinations were applied to generate an increasing diversity of plant species (1, 3 and 12 species) and/or distinct differences in C:N ratio of the litter (low, intermediate and high ratio). We prepared three single plant species treatments – red clover (*Trifolium pratense*) with low C:N ratio, cocksfoot (*Dactylis glomerata*) with intermediate C:N ratio and red fescue (*Festuca rubra*) with high C:N ratio and two mixture combinations – one in which the three above mentioned plants were mixed in equal weight proportions and the other composed of 12 plant species where 9 plant species (*Daucus carota*, *Arrhenatherum elatius*, *Bromus inermis*, *Alopecurus pratensis*, *Lolium perenne*, *Plantago lanceolata*, *Cichorium intybus*, *Potentilla anserina*, *Achillea millefolium*) were added to the three above mentioned. Samples were taken three and six months after litter exposition. On each sample occasion litter and underlying soil samples were taken. Three months after the start of the experiment the density of all animal groups studied was apparently affected by experimental manipulations. Type of litter significantly influenced density of nematodes and mites dwelling the litter but not in underlying soil. The reversed situation was observed in the case of collembolans. We found that litter diversity influenced animal communities to a less extent than litter quality. The abundance of nematodes in the litter was significantly affected by the C:N ratio; nematode density was significantly higher in the litter of low than in the litter of high C:N ratio. Bacterial-feeding nematodes from the genus *Panagrolaimus* dominated in the samples and in some cases were the only nematodes found. No significant differences in animal numbers between treatments were found six months after the litter exposure. Some interactions between nematodes, mites and collembolans were also analysed and their influence on litter decomposition was discussed.

Analysis of soil fauna distributions with spectral analysis

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Spatial variability pattern of soil fauna is an important aspect of soil biodiversity. Spectral analysis, a statistical technique which elucidates periodic patterns in soil, may help to understand faunal distribution pattern in tilled agricultural soil where tillage operations often lead to periodic features. Results from a grid and a transect study from tilled sandy soil in Northeast Brandenburg were analyzed by means of spectral analysis. The grid study was carried out on sandy soil in Möglin using 105 samples in a grid with a mesh size of 6 m. At each point number of earthworms was assessed besides other soil physical and chemical parameters. The transect study was carried out on tilled sandy soil in Seelow where 50 soil samples were taken in a transect normal to tillage direction with distances of 2 m between samples. Total numbers of enchytraeids and nematodes were assessed beside measurements of soil pH and amount of plant residues. Subsequently spectral and cospectral analysis was applied (Nielsen & Wendroth 2003). At both sites periodic features of soil fauna abundances were found which could be related to management operations. The results indicate that spectral analysis may help to better understand the relationship between soil faunal patterns and soil properties in tilled soil.

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Influence of landscape structure on soil macrofauna biodiversity in a cork oak wood (*Quercus suber*) area

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The present study is part of the BioAssess Project and in it we analyse the Portuguese soil macrofauna data set. Our aim is to study the changes in macrofauna biodiversity along a gradient of increasing land use.

The gradient was established in a Cork Oak wood area with six Landscape Use Units (LUU) characterized by an intensification of its use for economic activities ranging from a low managed cork oak forest to a intensive agricultural area, passing through a mixed use and pasture areas. In each LUU a sixteen point grid was established where the soil samples were taken in two consecutive years. The sampling was based on the TSBF protocol.

The data shows a significant decreasing in diversity, species richness and abundance along the gradient. However, these descriptors appear to be related more with landscape diversity than with increasing soil use. Partial correlations between macrofauna and remote sensing data show a significantly positive correlation between macrofauna biodiversity and the proportion of forested areas and a negative correlation with percentage of open areas, particularly agricultural areas. An evident positive relationship between biodiversity and the structural diversity of plant cover was also detected.

The biodiversity pattern is also influenced by the landscape spatial structure. The main characteristics related with macrofauna diversity are the patch shape and distribution. The higher levels of biodiversity were observed in LUUs with a more regular distribution and shape of the different patches. The increasing fragmentation, the lower structural plant cover diversity and patch shape irregularity appear associated with lower levels of biodiversity.

These results indicate that soil macrofauna seems to be a good biodiversity indicator of forest areas being also sensitive to spatial distribution of vegetation patches on mature cork-oak forests.

Effect of nutrient management practices on the abundance and diversity of soil invertebrates

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Soil organisms, the resource quality and the physical environment are three major determinants play an important role in the decomposition of organic matter. The present investigation was carried out to know the effect of conservation practices by altering the quantum of farmyard manure (FYM) and chemical fertilizer on the abundance and diversity of the soil invertebrates. An experiment was laid out with the plot size of 6 X 3.6 m, replicated thrice. Soybean variety Hardee was sown during Kharif season with the spacing of 30 X 10 cm under rain fed situation. The treatments included were **T1** Recommended FYM (10t /ha) + Rec. Fertilizer (25 : 60 : 25 kg NPK /ha)+ Phorate 10G at 1 kg a.i./ha + seed treatment with fungicide (Thiram + bavistin – 2g each /kg) + Herbicide (Lasso -20 kg /ha), **T2** Rec. FYM + 25% Rec. FYM + 75% Rec. Fertilizer, **T3** Rec. FYM + 50% Rec. FYM + 50% Rec. Fertilizer, **T4** Rec. FYM + 75% Rec. FYM + 25% Rec. Fertilizer, **T5** Rec. FYM + Rec. FYM, **T6** Rec. FYM alone, **T7** Rec. FYM (partially decomposed), **T8** Rec. FYM + Mulching (Glyricidia), **T9** Rec. Fertilizer alone and **T10** 50 % Rec. FYM alone. The soil samples (400g) were drawn at fortnightly interval using the circular core-sampler up to the depth of 10 cm. The invertebrates were extracted from the samples using McFadyen high gradient funnel apparatus. The extracted invertebrates were sorted out in to different taxonomic groups under microscope. The diversity of soil invertebrates was worked out following Simpson index.

The results revealed that there was no significant difference in abundance of invertebrates among the treatments at the end of two and a half year study. However, the treatment with Rec. FYM + 75% of additional FYM + 25% Rec. Fertilizer recorded highest abundance (7.05 /sample) and diversity (0.35) of invertebrates. The same treatment registered significantly higher diversity compared to other treatments but on par with T2, T3, T6, T7 and T8. Recommended package of practices (4.68 animals and 0.24 index) and chemical fertilizer alone (4.21 animals and 0.26 index) treatments recorded both lower abundance and diversity of invertebrates compared to the conservation practices. Maximum abundance and diversity of invertebrates was noticed during second fortnight of June and first fortnight of September, respectively. Minimum of these two were noticed during summer months. This is evident from the present study that increased quantum of FYM and reducing the chemical fertilizer helps in improving the abundance and diversity of soil invertebrates, microbial biomass and organic carbon which provided sufficient food for the soil organisms. Further, T4 also recorded 60 and 10.5% higher grain yield over T9 and T1, respectively at the end of third season.

The impact of urea fertilizer on soil free-living nematode population in a spring-wheat field, Northeast China

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The objective of this study was to evaluate the effect of urea fertilizer on nematode population and its trophic structure at different growing-stages in a spring-wheat field. We hypothesized that the application of urea fertilizer and its different transformation stages will have a significant effect on soil free-living nematode community composition.

In order to determine the effect of urea fertilizer, two different inhibitors that affect the release of ammonium were used. At the study site, urea and the inhibitors (1) N-(n-butyl) thiophosphoric triamide (NBPT) was selected as urease inhibitor, and (2) dicyandiamide (DCD) as nitrification inhibitor, were applied before sowing. A total of five treatments were: control (C); Urea (U); Urea+NBPT (UN); Urea+DCD (UD), and Urea+NBPT+DCD (UND).

The obtained results showed that the application of urea fertilizer can positively influence soil nematode population and its trophic structure. The total number of individuals and the plant-parasite trophic layer increased with the addition of inhibitors, where C>UND>UN>UD>U. A tendency of increase in microbivorous nematodes followed by increase in NH₄⁺-N was obtained in the UND-treated plots, elucidating the nematode trophic function. Throughout the wheat-growing season, the omnivore-predators were the smallest trophic group, with no significant effect on NH₄⁺-N and NO₃⁻-N values. Among the ecological indices of soil free-living nematodes, higher values for diversity index (H'), richness index (SR), evenness index (J) and the ratio of bacterivores-fungivores to the plant parasites (WI), were obtained in the urea-treated plots compared to the control plots. The F/B ratio was found to be the most effective index for distinguishing differences in nematode community structure among different treatments during the study period. According to the F/B ratio, the bacterial decomposition pathway was dominant and plays an important role in nutrient cycling in the urea-treated plots, while fungal decomposition pathway was more important in the UN- and UD-treated plots.

Evaluation of an agroecological method by means of soil fauna

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In the past few years, it has been demonstrated that the reason for the increase in the loss of organic material and soil degradation is due to the destruction of the fauna, which regulates these processes (Lavelle and Barois, 1988, Lavelle, 1996). In Cuba, there is scarce knowledge of the influence of the macrofauna with the application of diverse agroecological methods, like the conversion of a pasture in an agroecosystem. The objective of this research was to characterize the macrofauna in pastures where there is a combination of cattle raising and agriculture to understand the state of the conservation of the soil. We evaluated three areas with agroecological management: Pasture, pastured covered with trees (Forage) and multiple cultivation area in Cangrejeras, La Habana, Cuba. Macrofauna was sampled during the rainy and dry season, from May 1996 to September 1999 and later, from January to August 2002. Each time, three soil samples were taken (25cm X 30cm X 30cm) by the TSBF methodology (Anderson and Ingram, 1993). The invertebrate were extracted manually. The earthworms were preserved in a 4% Formalin solution and 70% alcohol and the remaining fauna in 75% alcohol. In the first cycle of sampling, eight groups of the macrofauna were found in the area of Forage and six were found in the other two areas. While the second cycle showed new taxa (10, 12, and 12) in the Pasture and Forage respectively. Oligochaeta and Formicidae were dominant in pastoral areas, while Isopoda, Gastropoda, and Diplopoda were dominant in fodder areas. Formicidae, Diplopoda, and Gastropoda were dominant in cultivation areas. The Kruskal-Wallis test and the SNK demonstrate that the distribution and abundance of major macrofauna groups respond first to the season of the year (specifically the rainy season) more than the management of each parcel, although during the rainy season the density of the macrofauna in the Cultivate was 3,8 times more than the Pastoral and the Forage, while during the dry season this same parameter was five and two times higher than the Pasture and Cultivation areas. In Cultivation area the application of organic fertilizer (compost, worm humus and harvest waste) and the addition of long term plants like banana and yucca, which add more litter to the soil making a positive influence in the increment of those population. According to the structural and functional macrofauna composition in the Pasture, Forage and Cultivation areas, we can consider that the agroecological methods that were been used help the establishment of those communities.

Key words: agroecosystem, Oligochaeta, Diplopoda, Formicidae, Isopoda, Gastropoda.

Effects of cattle grazing on soil amoeba biodiversity in Mediterranean grassland

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The effect of cattle grazing pressure on the biodiversity of soil amoeba was studied in Mediterranean grassland in northeastern Israel. Three areas with different levels of grazing intensity were examined: (1) area with high grazing pressure of 1.1 cow ha⁻¹ year⁻¹; (2) area with moderate grazing pressure of 0.55 cow ha⁻¹ year⁻¹ and (3) control- no grazing for almost 18 years.

Soil samples were collected from the upper (0-10 cm) soil layer during the autumn before the onset of the rainfall season from each of the three treatments (total of 24 samples). Soil samples were used to determine soil moisture, organic matter, total nitrogen, and amoeba biodiversity.

Soil moisture was found to reach a maximum mean value (8.7 %) in the high grazing intensity treatment while the mean lowest values (6.3 %) were measured in the moderate grazing area. The trend for organic carbon values as well as total soluble nitrogen showed a similar pattern, where the values obtained in the moderate pressure grazing area were found to be significantly higher ($p < 0.05$) in comparison to the control and high pressure grazing areas.

A total of 30 amoeba species was found in the soil samples collected, of which *Vanella* sp. and *Platyamoeba* sp. were found to be the most abundant species in all the samples. Species diversity was found to be significantly ($p < 0.05$) higher in the moderate grazing area in comparison to the high and control grazing management sites.

These preliminary results suggest that linkage between soil organic carbon, moisture level and availability, and nitrogen concentration in response to different grazing managements, is one of the most important regulators of amoeba population diversity.

The frequency of soil invertebrate taxa in the Congolese eucalypt plantations

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Eucalypt plantations are widely spread in tropical countries, especially for pulpwood production. In Southern-Congo, large areas of savanna, located on very poor sandy soils, seldom used for agriculture, have been exploited since 1978 through plantations of fast growing trees, mainly *Eucalyptus*. These are grown industrially, cut when seven years old, and regrown for three rotations. Industrial and experimental plantations at Pointe Noire cover about 40000 ha.

Because a common statement is that eucalypts “sterilizes” the soil, the main taxa of soil macrofauna were studied in savanna and in eucalypt plantations of various age and status, either first rotation or second or third rotation. Soil macrofauna in young plantations was very poor. However a trend to increasing macrofauna with increasing plot age, whatever the number of rotations, was shown through several previous studies, emphasizing the increasing biological activity in soil (Mboukou-Kimbatsa et Bernhard-Reversat 2001).

The overall studies resulted in more than 20 plots of various ages sampled, with generally ten samples per plot. So more than 200 samples were obtained according to the T.S.B.F. method (J.M. Anderson, J.S.I. Ingram, 1993). Each sample was a monolith of soil, 30 cm deep and 25 x 25 cm square. Samples were hand sorted and all visible invertebrates were removed.

This sampling was used to estimate the frequency of occurrence of the different taxa among plots and among samples. The comparison of taxa frequency to their density allowed to assess some characteristics of taxa distribution, with the aim of a better knowledge of the future changes of soil biology in eucalypt plantations. A great diversity of results was obtained according to the taxa.

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Effects of understory vegetation management in soil macrofauna from cork-oak forests in South Portugal

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“Montados” are a particular Mediterranean ecological system, which can be found in Southern Portugal. Portuguese “Montados” are man-made ecosystems, dominated by cork-oak trees and mainly used for cork oak production, but also for agro-pastoral uses. Some of “Montados” areas in Portugal have been subject to sustainable management, in order to improve its production, but also to keep this ecological system’s high biological diversity. In order to evaluate the effects of “Montados” vegetation management on its soil fauna, six areas were defined in a farm in Alentejo province where this management takes place (shrub are regularly cut in different areas of the farm and left in place as standing stock biomass). There were two criteria used to define these areas: the time spent since shrub was cut and the presence of cattle. Following those criteria, a control (non disturbed) area was defined, plus four areas with different times since shrub was cut (1 year, 2 years, 3-4 years and 4-5 years) and a pasture area. The soil fauna was sampled using “pitfall” traps, in groups of nine per area, and sampling took place in Autumn 2003.

A total of 2671 individuals were caught in the traps. Analysing biodiversity descriptors, no major differences on the total number of individuals and taxa per sampling area were found. However, a PCA clearly separated areas with high shrub density from managed areas and pasture. Some taxa (e.g., from Orthoptera and Staphylinidae) showed a more close relationship with recently intervened areas and pasture, presenting there higher number of individuals and taxa when compared to control and areas where shrub has been growing for a larger period of time. On the other hand, the Hymenoptera, the Scydmaenidae and insect larvae showed an opposite trend, existing in larger number in areas where shrub was cut recently. These taxa were closely associated to the control area.

Overall analyses show that some differences can be found on “Montados” soil macrofauna due to vegetation management, and that, in some groups, those effects can endure even some years after understory cut. These results highlight that even when sustainable forestry practices are used, it is necessary to take into account the spatial extent and time frame they are applied.

The small-scale diversity of free-living soil mites (Acari: Oribatida, Gamasida) along a gradient of land use types in New York

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Because of their small body sizes and restricted orientation in space, populations of soil mites are thought to exist below the scale of ecosystem-level processes. Significant spatial heterogeneity in the abundance of individual species is also common. This study tested the hypothesis that there is no relationship between landscape-level factors (land use type) and a local small-scale diversity of soil mites using a generalized gradient of land use types in central New York, USA.

The effect of land use type, separated from the effect of geographical location, was statistically significant for Oribatida and not significant for Gamasina. We suggest that the difference between the two groups reflects their ecology. Gamasine mites are able to exploit spatially and temporarily restricted habitats. Therefore, a gamasine community may exist on spatial and temporal scales too fine to be affected by our land use practices, and is not correlated to landscape-level disturbance gradients. On the other hand, the temporal scales at which oribatid mites exist and the temporal scales at which human-dominated ecosystems are managed are close. With their long life span, low fecundity, slow development and low dispersion ability, oribatid mites can be a robust indicator of environmental stress at the same scale as we perceive it.

Impact of the FBO (patented) technology on soil macrofauna

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Response of enchytraeids to tree girdling and clear-cutting

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To separate mycorrhizal root respiration from heterotrophic respiration, large-scale tree-girdling experiments have been performed (e.g. Högberg et al. 2001, *Nature* 411:789-792). Tree-girdling involves stripping the stem bark to the depth of the current xylem at breast height terminating the supply of current photosynthates to roots and their mycorrhizal fungi without physically disturbing the delicate root-microbe-soil system. Girdling experiments have so far been made in stands of Scots pine in Sweden and Germany. These experiments were used to study the impact on various soil fauna groups, because girdling should cause lesser effects on nitrogen concentrations, soil water levels and root mortality than clear-cutting or trenching. Despite less disturbance, enchytraeids seemed to react similarly to girdling as to clear-cutting, i.e. with 2-3-fold increases in population density for at least top-soil species like *Cognettia sphagnetorum*. There are several possible explanations of this increase, for example, increased moisture levels and increased production of substrate in the form of root/mycorrhizal litter. However, another possible explanation is that active ectomycorrhizal fungi can affect population number and biomass of enchytraeids negatively. Arguments for this possibility will be discussed.

Changes in subalpine soil fauna of the Carpathians induced by clear cutting of *Pinus mugo* scrubs

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The *Pinus mugo* scrubs form a characteristic vegetation belt (As. *Rhododendro kotshyi* - *Pinetum mugii* Borza 1959, emend. Coldea 1985) at the upper limit (1,500 - 2,200 m a.s.l.) of the forest in the Romanian Carpathians. These scrubs proved to have the most favourable biocoenotic structure for the accumulation and storage of solar energy, and in the same time for the protection of biotopes from the inferior belts.

The cutting of *Pinus mugo* scrubs in the mid-century, for the extension of grazing area, has proved to be an ecological error. The secondary grassland of *Hyperico alpigeni* - *Callamagrostetum villosae* Pawl. et Wallas 1947 cover the cleared areas, with patchily distributed remnants of the previous peaty horizons, peat moss, sod and bare or eroded soils.

Studies on soil fauna relationships to vegetation and soils in the newly installed biotopes were carried out in the Cornedei Mt (the Maramures Mts). Five sites, situated between 1500 and 1700 m altitude, with 2, 4, 5, 11 and 21 years old clearings, as well as an adjacent uncleared *Pinus mugo* scrub and an old secondary grassland (considered as controls) were studied comparatively. Neighbouring spruce fir forests were also studied.

In the cleared areas lysimetric experiments showed that in the lack of shrubs and moss layers, which acted like a water retaining sponge, a great amount of precipitations is lost as stream or torrents. The disequilibrium of water balance leads to a change of the humid microclimate to a relatively dried one. Pedologic research shows a process of degradation of soil profile, with thinning of organic and humiferous horizons; erosion and solifluxion are frequent.

Evolution of soil fauna is assessed by changes in species structure and density of free living nematode, lumbricid and Collembola communities.

More than 150 nematode, 47 collembola and 11 lumbricid species were identified. Common, immigrated and lost species from different, old and new, biotopes are discussed.

The soil fauna of new habitats loses between 18-55% of species characteristic for the potential *Pinus mugo* ecosystem.

The biomass of soil fauna in scrubland is dominated by earthworms of the so called "community with *Dendrobaena alpina*", while in grasslands by the community with *Allolobophora rosea* - *Dendrobaena clujensis* occurs.

Species structure and ecologic parameters and groupings of the earthworm, nematode and springtail communities of the new biotopes installed in the clearings, as well as the composition of new plant cover, differ according to the age of clearing.

After the shock of removing the original scrub vegetation, a tendency of re-organisation of the edaphic communities is observed, but even after 21 years it do not match the fauna of the aimed secondary grassland.

Factors influencing earthworms community and population structures on post-industrial areas

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Application of earthworm in soil re-cultivation and recreation in post industrial ecosystems make a big challenge for temporal applied zoology. The sediments of the Krakow Soda Works “Solvay” have undergone a land reclamation in different ways: older sediments traps were left without any re-cultivation practices meanwhile the newest ones were reclaimed using standard method (new soil cover and plant sifting). The effect of different treatments on community and population structure of earthworm were estimated during consecutive years 1999-2000. Six localities differing in time of establishment, reclamation processes, vegetation type and soil properties were chosen.

Nine species were recorded, among which *A. caliginosa* occurred on all localities, being also the most abundant. Two other species, *L. rubellus* and *D. octaedra*, which are epigeic species, become most important in forest assemblages and were characteristic for communities of older succession processes. Abundance of adult forms as well as total biomass were significantly affected by litter depth ($r=0.75$, $p<0.05$, $r=0.917$, $p<0.001$ respectively). Species richness however was connected with higher amount of macroelements and mean plant height. Shannon diversity index and its evenness negatively correlated only with forestation ($r=-0.67$, $p<0.05$, $r=-0.68$, $p<0.05$ respectively). Niche overlap (a Pianka) for all analysed species extracted two groups differing in environmental requirements. First contained epigeic earthworms, closely related to plant succession (PCA results), the other one grouped endogeic and anetic species correlated significantly with litter depth and plant density. Community structure of earthworms don't reflects succession changes in postindustrial habitats, but is strongly affected by microhabitat factors in local scale (mainly litter depth and plant density).

Comparing effects of conventional and organic farming practices on soil functional properties and the associated soil mesofauna

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Due to demands on their agricultural sectors many developing countries have increasingly turned to chemical biocides to combat pests. This may also have negative effects on beneficial, non-target soil organisms, since varying amounts of the chemicals are reaching the soil.

The protection of soil biodiversity and its accompanying functions is an important goal for soil conservationists aiming at providing ecologically relevant solutions to problems in the agro-ecological field. Soil processes, soil community structure and soil community functioning are viewed as important endpoints in assessing the risk of chemical management practices on soils (Eijsackers and Løkke, 1992).

In recent years the concept of organic farming was developed more vigorously in an effort to decrease or even eliminate the use of pesticides. The extent to which beneficial soil organisms and their roles in soil processes can benefit or be protected by converting from conventional to organic farming practices remains an important question.

The aim of this study was to determine whether the activity and abundance and diversity of soil organisms are influenced differently by different management practices viz., organic management versus conventional management (which includes pesticides).

By measuring the changes in the feeding activity of soil organisms caused by chemical contaminants, a better understanding may be gained of the effects of toxic or other factors on the decomposition process. The bait-lamina test was used to assess the feeding activity of the soil organisms in the field. Soil microcosms with bait-laminae were also used to study feeding activity under laboratory conditions. Soil samples were taken from which springtails were extracted with a Tullgren extractor and counted. Soil parameters such as pH, water holding capacity, organic matter content, soil texture and soil respiration were determined.

Results indicate that abundance of springtails was highest at the organically treated soil and lowest in the conventionally managed soil where pesticide application took place. Also the CO₂-flux in the organically treated soil was the highest, indicating a higher biological activity associated with higher springtail densities. The results of the bait-laminae tests in the microcosms revealed that the soil receiving organic treatment had a substantially higher feeding activity, than the soil that received the conventional treatment.

We conclude that this study provided some evidence that the organic management practices used, did show higher soil faunal feeding activity and abundance over the short term compared to conventional practices.

The effect of cultivation techniques on earthworms

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Modern agriculture systems using intensive tillage with heavy machinery has had a profound effect on earthworm populations. Intensive cultivation by mechanical disturbance completely changes the environment in which earthworms live, destroying the habitat, changing the soil temperature, moisture and availability of food (Edwards, 1983). Anécique species such as *L. terrestris* and *A. longa* which require a supply of surface litter and have relatively permanent burrows are the species most adversely affected by repeated soil disturbance, while smaller endogeic species such as *A. chlorotica* and *A. caliginosa* are less affected and can benefit from the incorporation of crop residues into the soil (Edwards, 1983).

Increased environmental awareness and encouragement of more environmentally friendly farming methods have resulted in increased interest and research into minimal cultivation which allow earthworm populations to increase gradually in degraded soil (Fortune, 2001; Mele and Carter, 1999). Earthworms, especially the larger deep-burrowing species are favoured by minimum tillage and direct drilling compared with conventional methods of cultivation (Curry, 1994). Populations benefit from tillage practices which return a high portion of crop residues to the soil, particularly when the residues remain on the soil surface. When straw is left on the surface there is an increase in organic matter that is beneficial to certain earthworms such as *A. longa* and *L. terrestris*. Consequently, a combination of factors including mulching and cover crops and reduced tillage are among the key factors permitting a consistent recovery of earthworm biomass and species number (Paoletti, 1999).

This poster presents the results of a study investigating the effect of different cultivation techniques on earthworm species abundance and biomass from sampling sites in the UK, Belgium and Hungary. The primary hypothesis of the PhD being that minimum cultivation techniques are beneficial to earthworm abundance. The results will illustrate the differences or similarities between earthworm species abundance in ploughed and minimum cultivated soils under different crops across Northern Europe.

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Which taxonomic level for bio-indication using soil macro-invertebrates?

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Interest in the quality and health of soil has been stimulated by recent awareness that soil is vital to the global ecosystems function. With the increasing pressure to produce more food, fiber and energy to meet world demands on a limited area, there is an unprecedented need to address global concerns about soil degradation.

During the last decades an important number of studies has been realised on soil macro-invertebrates as bio-indicators of soil quality. These studies revealed their high sensitivity and accuracy to reflect soil status and thus their adequacy to be used in bio-indication (Paoletti ed., 1999; Lobry de Bruyn, 1997; Rodriguez et al., 1998; Frouz, 1999).

The main disadvantage often outlined of using terrestrial invertebrates as a broad and rapid tool to evaluate soil status and environmental changes by a large range of actors is the difficulty found to identify species level.

The aim of this paper was to test the usefulness of higher taxa analysis at genus, family and order level to estimate the bio-indicator power of soil macro-invertebrates at these taxonomical levels compared to the species level.

For the sake of robustness four regions in France were sampled in which forest, grasslands and cropped systems represented a wide range of different situations.

A total of 630 samples of soil macro-invertebrates were collected and identified up to species level. Singletons and doubletons were removed from the data set. A correspondence analysis was performed at order, family and species level for each study site. Spearman's correlations were realized between the coordinates of the sites positions on the first two axis of the multivariate analysis. Results showed high correlations ($R=0.76$) statistically significant between the species and the family level for all study cases. Concerning correlations between order and family level there was a variable response between sites and even between axis. Two of four studied sites (Ile-de-France and Auvergne) showed a high correlation between orders and families ($R=0.82$), sites located at Bourgogne region showed a statistically significant correlation for the ecological factor highlighted by the second axis and in Centre region there was no correlation. The variability of the responses was associated to different management systems and to different axis.

Regarding these results it has been suggested that the family level could be used in bio-indication with soil macro-invertebrates.

Distribution of soil Gamasina mites (Acari, Mesostigmata) on the seacoast-inland gradient in coastal meadows

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Factors affecting distribution and community structure of Gamasina mites within the soils of coastal meadow ecosystems were investigated. Soil samples were collected along two transect lines (120 and 50 m long) laid across the meadow from the seacoast to inland in June. Sampling was made in regular distances (10 m) on transect line. One soil core (23 cm² x 10 cm) was taken for extraction of mites at each sampling site. Soil mites were extracted by means of Tullgren funnels. Separate samples for determination of soil pH and salinity were taken, the depth of soil organic horizon was measured and description of dominant vegetation was made.

Coastal meadows showed high density of gamasina mites (7500 ind./m²) and high species diversity (38). The dominant species were *Holoparasitus excipuliger*, *Pergamasus vagabundus*, *Hypoaspis praesternalis*, *H. aculeifer*, *Veigaia nemorensis*, *Dendrolaelaspis angulosus*, *Cheiroseius necorniger*, and *Prozercion kochi*.

Nonmetric multidimensional scaling (NMS) yielded 2-dimensional solution (final stress value 15.84). Axis 1 explained 36.7% of the total dispersion and was correlated with the thickness of soil organic horizon O ($r=-0.58$). This axis coincided also with soil moisture gradient characterized by dominant vegetation. It was interpreted as effects of soil fertility and moisture regime on Gamasina community. Species *H. aculeifer* had high negative correlation with this axis ($r=-0.682$), it was found only in mesophytic and xerophytic habitats on the elevations of relief. *H. praesternalis* had high positive correlations with axis 1 ($r=0.736$) and was present mainly in hygromesophytic or hygrophytic habitats with thick O horizon located in depressions of relief. Axis 2 explained 38.1% of total dispersion and had no correlations with the measured edaphic factors. It explained distribution of species *Neojordensia levis* ($r=0.756$) that was found mostly in samples with lower total numbers of gamasina mites ($r=-0.324$). Neither soil pH, nor salinity appeared to be significant factors in the distribution of soil gamasina mites in the coastal meadow soils. The governing factors responsible for changes in the abundance and community structure of Gamasina were those connected with changes of soil fertility and moisture on the sea-inland gradient.

The impact of cattle pasture on small annelids (Annelida: Enchytraeidae, Tubificidae, Aeolosomatidae) in grasslands of the White Carpathians (Czech Republic)

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Pasture has shaped much of the landscape in Europe as well as on other continents. Another traditional use of grasslands in Europe is hay production on meadows. In most of Europe both these traditional types of management have become little profitable. In the White Carpathians, a small mountain range on the border between the Czech Republic and Slovakia, sustainable ways of conservation management for the extensive meadows rich in plant species are looked for, pasture being assumed an economically more viable alternative. The soils are cambisols of low acidity and fine texture on flysh and heavily prone to erosion. Pasture has several effects on soil, the major ones being soil compaction, removal of biomass input in most of the affected area by grazing, massive input of dead organic matter and nutrients in dung patches, and long-term changes in the character of the dead organic matter due to changes in vegetation. Within a project on the effect of pasture on White Carpathian grasslands, enchytraeids and other small annelids were investigated on two sites (4 km apart), both with a pair of adjacent plots. On each site one plot was managed as a hay meadow, the other grazed by cattle. The plots were sampled on four dates during a one-year period starting in autumn 2002; 8 soil cores down to 12 cm depth were taken per plot and date. Soil cores were vertically subdivided into 3 cm thick layers, small annelids were extracted by wet funnel extraction, counted and identified alive. Densities reached up to 13 750 (S.E. 3 344) individuals m⁻², but pronounced draught during 2003 led to very low densities, thus also complicating data interpretation. On both sites a difference in the vertical distribution of enchytraeids was found between meadow and pasture: in the pasture plots a higher percentage of individuals was present in the upper 6 cm of the soil profile. Species numbers of enchytraeids ranged from 13 to 17, slightly more species were recorded in the meadows. Dominance of species changed from date to date and also differed between the individual plots. The most abundant species were *Enchytraeus buchholzi* agg., *Fridericia isseli*, *F. semisetosa*, *F. galba*, *F. bulboides*, *F. bisetosa*, and *Cernosvitoviella atrata* on the meadow sites, on the pastures also *Achaeta* spp. *Henlea perpusilla* occurred mainly on the pasture plots and *Henlea ventriculosa* exclusively there; these are species known for their tolerance to disturbance. The only data on enchytraeids from the White Carpathians have been published recently by the authors, the present study adding several first records for the Czech Republic (however, species identity still requires verification in some cases): *Fridericia rensinata*, *F. cf. globuligera*, *F. cf. maculatiformis*, *Achaeta cf. urbana*, *Marionina* sp. 1. Of the other small annelids, *Rhyacodrilus falciformis* (Tubificidae) was recorded on three plots, *Aeolosoma hemprichi* and *A. cf. niveum* (Aeolosomatidae) on a single plot. These species were missing after the summer draught.

Effects of different mulch and fertilizer treatments on soil fertility variables in a degraded Coconut - Cupuaçu (*Cocos nucifera*, *Theobroma grandiflorum*) plantation in central Amazonian

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In two field experiments different mulch quantities and qualities were tested with the objective to define the manageable factors acting on soil fertility in the Tropics, independent from the specific agricultural system. The experimental plots were set up in a completely randomised block design in a degraded area of an abandoned *Cocos nucifera*/*Theobroma grandiflorum* plantation.

In the first experiment three different mulch qualities were tested. While the autochthonous grass cover was cut and used as low quality material (nutrient poor), leaves of *Flemingia macrophylla* were introduced in the experimental plots with the aim to raise the substrate quality (e.g. decomposability, nutrient content). A mixture of both, grass and legume leaves, was taken as a medium quality. The factors mulch (three levels) and mineral fertilization (two levels) were combined to six treatments in a factorial design with 2 replicates in each block.

In the second experiment three different quantities of mulch material were tested, using a mixture of branches or twigs and leaves of the legumes *Tephrosia candida* and *Pueraria phaseoloides*. The factors mulch (three levels + controle) and mineral fertilization (two levels) were combined to eight treatments in a factorial design with 2 replicates in each block. All treatments in both experiments were repeated 2 times/year over 2 years.

We expected effects of the treatments on the following dependent variables: abundance, biomass and community structure of soil macrofauna, microbial biomass, decomposition rates, soil organic matter content (SOM), C/N-ratio, base saturation and cation exchange capacity, bulk density and soil microstructure.

The idea behind is to improve soil fertility in tropical land use systems and especially their sustainability by increasing the long-term SOM content through additional organic matter input and melioration of the conditions for the decomposing soil fauna.

The project was supported by the SHIFT-program “Studies on Human Impact on Floodplains and Forests in the Tropics” of the German Federal Ministry of Education and Research and the Brazilian National Council for Research CNPq, project IDs: BMBF/DLR: 01 LT 0014 and CNPq: 690018/00-2; run duration: Oct 2000 – Sept. 2003. Project leader: Dr. Hubert Höfer.

Impact of atmospheric CO₂ enrichment and N fertilization on soil soil fauna and crop analysed by stable isotope ratio techniques (¹³C and ¹⁵N)

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At the Federal Agricultural Research Centre (FAL) in Braunschweig (Northern Germany) a large scale free air CO₂ enrichment (FACE) technique is used to assess effects of future atmospheric CO₂ concentrations on the C-turnover in the atmosphere-plant-soil system of an arable crop rotation (winter barley, rye grass as intermediate crop, sugar beet, winter wheat). Part of the plots are fumigated with an elevated atmospheric CO₂ concentration (550 ppm) compared to reference plots fumigated with ambient air (CO₂ 370 ppm). Management treatments in the field are according to local farming practice. One major objective of the FACE study is to trace the additional C on its flow from the atmosphere via the plants into the soil and to assess the impact of the elevated CO₂ supply on soil organisms.

CO₂ enrichment is carried out during the daylight hours in the course of the whole growing seasons. The CO₂ used for the FACE plots is depleted in ¹³C compared to ambient air which makes it possible to trace the fate of new C in different compartments of the system: a mean δ¹³C value of -20.5‰ is established in the CO₂ enriched environments as compared to CO₂ of ambient air (δ¹³C -9.8 ‰) in the control plots. Furthermore, subplots were fertilised with ammoniumsulfate which was labelled with ¹⁵N. The aim of the present field study was to quantify matter fluxes (carbon and nitrogen) related to important members of the decomposer food web in soil under possible future climate and nutrient conditions in an agroecosystem. The stable isotopic composition of Enchytraeidae and Collembola, roots and leaves of the crop (winter barley) and soil were analysed at 5 sampling dates in total during the growing season.

Up to now, no such detailed analysis of separate, strongly linked compartments in an agroecosystem had been conducted using stable isotope ratio techniques within a climate change scenario. The results revealed a time dependent uptake and flux of nitrogen from soil via plants and probably root exudates into decomposers. The nitrogen flux was reflected by a time-delay of increasing ¹⁵N values comparing the data of all compartments over the growing season. Enchytraeids and collambolans showed a delay in increasing ¹⁵N values compared to plant material. The nitrogen uptake by roots was higher under FACE conditions compared to ambient air. Differences in ¹³C values between FACE and ambient air conditions were highest in plant material and lowest in soil. Generally, a higher carbon uptake was observed in all compartments under FACE conditions.

Meta-analysis of soil tillage effects on earthworms

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Meta-analysis provides a quantitative method to integrate statistically results from separate studies on the same scientific question. Meta-analysis was initially developed for clinical, educational and similar research about three decades ago. More recently, this integrating statistical tool has become increasingly important in ecology and evolution as a means to combine and use result from numerous individual studies on a particular, common research topic in order to test a single hypothesis regarding this topic.

The aim of our study was to compile and analyse the global body of available data reported from arable field studies on soil tillage systems affecting earthworm abundance and biomass. Many studies have been published comparing conventional (mouldboard ploughing) and reduced tillage systems (e.g. no-tillage, conservation tillage, non-inversion tillage). A large number of primary literature was sourced and checked for suitability for inclusion in the dataset based on a catalogue of strict criteria concerning sampling, replication, data presentation etc.

In total, more than 70 studies fulfilled our criteria to be included in our database. These studies present results from nearly 100 field experiments conducted in 17 countries worldwide. About half of the studies were conducted in Europe, but none in Africa. Almost all studies reported higher earthworm abundance and biomass levels under reduced tillage treatments. A detailed, formal meta-analysis of the whole dataset incorporating all suitable separate studies was performed. Recommendations for data presentation and reporting will be given in order to encourage authors of future studies to report their work in such a way that it can be compared and synthesized.

The influence of livestock dung on the spatial and temporal distribution of exotic and native earthworms

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It is well known that organic matter in the form of dung is utilised as a food source by earthworms, but little has been reported on the preferences of earthworms for different types of dung. An experiment was carried out in spring in south-eastern Australia to evaluate the effect that dung from different livestock has on the spatial and temporal distribution of earthworms in a grassland environment. We were particularly interested to compare the responses of native Australian earthworms (Megascolecidae) with those of exotic earthworms (Lumbricidae and Acanthodrilidae). The attractiveness of dung from sheep, cattle and horses was measured by determining the abundance and biomass of the resident earthworm species under each dung type at varying times after adding the dung to the soil surface (0, 10, 20 and 30 days).

The earthworm community consisted of three exotic species, *Apporectodea trapezoides*, *Microscolex dubius* and *M. phosphoreus*, and two native species, *Spenceriella macleayi* and *S. bywongensis*. The native species comprised the majority of the abundance and biomass of the earthworms at the site. Both the number of days that the dung was available to earthworms and the type of dung influenced the numbers and biomass of the earthworms found beneath the dung pats. Significant interactions existed between time and dung type when all adult earthworms were considered as one group and also when adults were split into native, exotic and individual species. Whilst *S. macleayi*, *A. trapezoides* and the *Microscolex* species aggregated under dung, in particular horse and cattle dung, *S. bywongensis* showed no such response. The possible significance of these results will be discussed in terms of the management of dung in an Australian pastoral context.

An evaluation of the impact of anthelmintics on the grassland ecosystem using invertebrate dung decomposers as monitoring indices (dung beetle, earth worm, protozoa)

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Regardless of their mode of administration, anthelmintics such as ivermectin are excreted in the feces of livestock as a mixture of parent compound and metabolites.

Thus, the use of anthelmintics in farming has a potential impact on non-target invertebrates, including dung beetles, flies, earthworms, soil protozoa, and other organism that depend on dung and contribute to its degradation its grassland ecosystems. This study examined the impact of anthelmintics residues on the dung pat-degrading fauna in grassland.

1. The impact of ivermectin on dung-degrading insects living in grasslands - After ivermectin was pored onto the cattle, the samples were collected at 1, 3, 7, 14, 21, 28, and 35 days and bioassayed using the dominant dung beetles and fly larvae of the Hokkaido and Tohoku areas of Japan. Ivermectin residues attained maximal concentrations between one and three days after poring onto the cattle, followed by a linear decline in concentration up to day 35. Dung samples collected 1 to 14 days after ivermectin treatment were lethal to the larval development of *Digitonthophagus gazella*, a dung beetle introduced from the U. S. A.

2. The effects of the broad-spectrum anthelmintics ivermectin and moxidectin on the earthworm *Eisenia fetida* as shown by a laboratory study - Earthworms were assayed using dung pats to which had been added a serial dilution of ivermectin and moxidectin. The mortality rates of the earthworms were 3.6, 7.4, and 7.4% at ivermectin concentrations of 10², 10³, and 10⁴ µg/kg respectively, but no statistically significant differences were observed among the treatments. Moxidectin at 10⁴µg/kg caused 83% mortality, but no mortality occurred at concentrations of 10² and 10³µg/kg, indicating that moxidectin was more toxic than ivermectin at high concentrations but less toxic at low concentrations. The 10³ and 10⁴µg/kg ivermectin caused the cumulative weight of seven earthworms to decrease significantly by 11 and 18%, respectively, whilst 10⁴µg/kg moxidectin resulted in a 47% decrease. However, no reductions in single worm weight were observed for any treatment, probably because of the difficulty of detecting weight reductions using single worms. The amount of NH₄⁺-N in the soil decreased gradually with increasing concentrations of ivermectin or moxidectin. Considering that NH₄⁺-N is an excretory product of worms, this result indicated that earthworm activity was inhibited at high concentrations of both anthelmintics. Differences in soil NO₃⁻-N was not detected under any treatment, and there were no significant differences in soil pH.

3. Effect of anthelmintics on the growth of protozoan species - Soil protozoa were assayed using dung pats to which had been added a serial dilution of a formulation of ivermectin and moxidectin formulation. Two laboratory strains, *Paramecium caudatum* (strain SJ-5) and *Paramecium trichium* (strain YM-18a), and three wild strains isolated from soil, *Colpoda* sp. 1 (strain FF-2), Tetrahymeniidae sp. 1 (strain SSD-sp. 1), and *Halteria grandinella* (strain SI-Hal) were examined. Soil protozoan species, *Colpoda* sp. 1 and Tetrahymeniidae sp. 1, both known to be omnivorous dung-decomposer, were found to be stimulated by the anthelmintics, although their growth rates were often affected in relation to the amount of ivermectin and moxidectin. The growth rate of *Halteria grandinella*, a bacteria-feeder, was inhibited by the anthelmintics. The two wild omnivorous species had higher tolerance to both the anthelmintics and the inorganic substances, HgCl₂ and CuSO₄, than the two laboratory strains. The direct counts of ciliate were performed in the field plots that had been administered ivermectin series, and the amount of other protozoa quantity was calculated by means of MPN methods. Both results showed that soil protozoa were actually activated by the ivermectin.

Beetles community structures under different reclamation practices

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Differences in beetles community structures between not re-cultivated sixty-years old forest and ten years old re-cultivated meadow and shrubs were compared. On each localities three replicates of ten pitfall trap rows were arranged. Mean abundance of beetles was significantly greater on old forest stand than re-cultivated meadow. However no significant differences between localities in species richness nor non parametric indices of diversity (Shannon and Simpson) were recorded. Rank-abundance curves for communities newly established communities best fits to geometric model of distribution ($r=0.98$, $p<0.001$) which is characteristic for species poor communities, where a single environmental resource is extremely important, meanwhile old stand, without any reclamation practice is best fitted to lognormal distribution model ($r=0.99$, $p<0.001$) which is typical for more stable and well developed communities. Principal Component Analysis for $\log(N+1)$ transformed matrix of abundances described well 60% of total variance. Two clear groups of species transects were derived: one concentrated assemblages of both reclaimed and newly established communities and the second one old non-reclaimed forest stands. Significant feature of trophic guild structure in all three communities is lowest abundance of decomposers meanwhile predators predominate on non re-cultivated old site and herbivores on reclaimed young stands. Structure of beetles communities is less connected with reclamation processes and indicate that the time of succession of the communities is more important.

Enchytraeids densities in different monocultures and mixed forests (preliminary results)

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We examined soil community of enchytraeids in 8 tree-species monocultures in Siemianice, Central Poland. The study area consisted of 18 square plots (20 x 20 m). The monocultures comprised the conifer (*Pinus sylvestris*, *Picea abies*, *Larix decidua*) and five deciduous tree species (*Quercus robur*, *Carpinus betulus*, *Fagus sylvatica*, *Acer platanoides*, *Tilia cordata*). Each of six species was present on two experimental plots and the oak and spruce grew on three plots. All trees were 33-yr old and were located on uniform sandy brown podzolic soil, forested previously with Scots pine. Results of this study show that the species diversity differs in the studied monocultures. There were fewer species in coniferous than in deciduous forest. There were no significant differences in density of enchytraeids between tree species traits and ecosystem processes. Therefore results of this preliminary study can be used for future analysis of the relationship between enchytraeid fauna and the soil conditions characteristic for different forests.

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Development of millipede and centipede assemblages in restored species-rich meadows on arable soil

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Grasslands of the temperate climatic zone represent in majority the result of long-term impact of human activities. Despite of this fact, in many cases grasslands possess by high diversity and are of nature conservation importance. In the Czech Republic, since 1920 a quarter of the total historical grassland and pasture area has been transformed into arable soils by ploughing. Recently, changes in agricultural policy and economic conditions have brought about problems of how to transform recent arable land back into grasslands and how to ensure high diversity of these restored areas. One possible way respecting regional and nature conservation aspects is the restoration of grasslands by sowing with native haymeadow seed mixtures and regular mowing corresponding to traditional management of meadows.

The objectives of a field experiment carried out in the White Carpathian Mountains (Czech Republic) were to assess the feasibility of different recreation techniques, from regional seed mixtures to natural regeneration as well as intermediate methods using sown strips, and to provide information about the vegetation and soil fauna development in used recreation treatments. To obtain data about the successional development of millipede and centipede assemblages in four types of treatment and control (arable field), soil sampling and pitfall trapping were used during the years 2000-2003. The observations showed subsequent increase of qualitative and quantitative parameters of both studied invertebrate groups. Initial phases of successional development of millipede and centipede assemblages were represented in all treatment variants by eurytopic pioneer species characteristic for disturbed habitats. The millipedes *Brachyiulus bagnalli* and *Polydesmus denticulatus*, and the parthenogenetic centipede *Lamyctes emarginatus*, all occurring in low numbers on control arable field, represented the first colonizers of treated plots. Subsequently the densities of millipedes and centipedes increased, nevertheless after four years their values were still relatively low (29 and 100 ind.m⁻² in maximum for millipedes and centipedes, respectively). Animal resources existing in surrounding habitats affected the development of populations of some species, as showed their increasing epigeic activities. Small differences in assemblages of individual types of treatment were found although the indirect influence of treatment on development of soil fauna throughout the diversification in vegetation cover, variability of microsite conditions and available food resources was presupposed. The results indicate that even the more economic variant using only sown strips of regional seed mixture, sufficient for vegetation regeneration, served acceptable conditions for recolonization and restoration of soil invertebrate faunas. Differences in development of saprophagous invertebrates (millipedes) and predators (centipedes) during meadow restoration are discussed.

The research was supported by the Grant Agency of the Czech Republic, project No. 526/02/0036.

The soil mesofauna coenoses of non-used grassy fields margins in the agricultural landscape – A pool of bioindicators to assess the impact of landuse on non target sites?

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The typical coenosis of a biotope is the fingerprint of all ecological processes within a site. Due to environmental conditions species exist in a dynamic equilibrium of community composition. Changes of site conditions are followed by changes in community structure. Thus it should be possible to use these multi-species-systems for bioindication. The known reaction of the coenosis under specific conditions permits a forecast of its structure.

The intricate relationships of soil arthropods with their ecological niches in the soil provide good starting points for bioindication of changes in soil properties and impact of human activities (VAN STRAALLEN, 1998). Regularly recurring biocoenosis (taxocoenosis) of Collembola are presented. Research was carried out on grassy field margins in three different agricultural landscapes of Germany (Jülicher Börde, Leipziger Tieflandsbucht, Area of Mainfranken) during 2001-2003. The selection of sites with similar site-conditions was a precondition. Based on the knowledge of phytosociology the study was carried out on sites of the same vegetation unit by an inductive approach (*Artemisia vulgaris-Arrhenaterum elatius*-community [ruderalized tall oatgrass meadow]). The plant community reflects as phytocoenosis (and therefore as part of the biocoenosis) the ecological properties of the site (KRATOCHWIL & SCHWABE, 2001). According to this ecological principle also the faunistic part of the biocoenosis should be a reflection of the environmental conditions. Thus under similar conditions a recurring zoocoenosis should be found. Basically this was already shown for the special case of the soil mesofauna (STRENTZKE 1952, KNÜLLE 1957, WEIGMANN 1973, KUZNETSOVA 2002). The aim of *these* studies was to characterize different communities and the ecological range of species along a vegetation-gradient. The *present* study investigates the coenoses of a single vegetation type. Differences in measured site-parameters (e.g. soil type, pH, C, N, P,...) are related to differences in phyto- and collembolan coenosis.

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Response of soil fauna to clear-cutting – different methods, different results?

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The impact of deforestation on soil fauna is often studied problem recently. The most studies are focussed on boreal forest however. In this study, the influence of timber harvesting on soil invertebrates in floodplain forests was investigated. The research plot (cca 50 × 100 m) in floodplain forest (*Quercus-Ulmetum*; Litovelské Pomoraví Protected Landscape Area, Czech Republic) was clearcutted in November 2002. Wood rests left on the place after carrying the cutted trees away were chipped and scattered throughout whole area in March 2003. Clearcutted area was fenced and planted with trees (oak, elm, lime; 8:1:1) using heavy forest machines. In this paper assemblages of different groups (Isopoda: Oniscidea, Arachnida: Opiliones, Chilopoda, Diplopoda, Symphyla, Coleoptera: Carabidae) of floodplain forest and neighbouring clearcut area are compared. Pitfall trapping and heat-extraction of soil samples were used for collecting of soil invertebrates from April 2003.

Pitfall trapping: Species diversity and abundance of clearcut area were comparable with those of floodplain forest. However, higher number of ground beetles species and increasing abundance of them (namely genus *Poecilus*) were observed in clearcut area. From the other taxa, a woodlice *Ligidium hypnorum* as well as millipedes genus *Glomeris* were dominating in clearcut area. On the contrary a woodlice *Protracheoniscus politus*, millipedes of genus *Unciger* and ground beetles *Carabus ulrichii* and *Abax parallelipedus* were dominating in floodplain forest.

Heat extraction of soil samples: Species diversity was quite similar in both study sites. In floodplain forest the most dominant woodlice were *Trichoniscus pusillus* and *Hyloniscus riparius*, a centipede *Strigamia acuminata* and a millipede *Melogona voigti*. Much different situation was observed on assemblages abundances. Apparently higher abundances of all groups (including symphylans) were detected in forest (several fold).

The results clearly show how insufficient could be rating of influence of forest management on soil fauna based just on superficial epigeon. Deforestation itself could have no negative impact on the structure of epigeic assemblages (final heterogeneity could be even higher caused by migrations of open areas species as *Poecilus cupreus* and *P. versicolor*). However, the influence of attendant processes as using of lorries for timber-transport, using of planter machines etc., usually negatively influenced structure parameters of upper soil layers, moisture and/or food offer for soil invertebrates. Looking under surface, the final impact of deforestation on soil fauna can be very negative.

Indirect gradient analysis at subplot, plot and parcel level of prorated and non-prorated data of earthworm communities from agro-ecosystems in a temperate climate

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In this study we investigated how earthworm communities of agricultural systems vary in earthworm abundance, biomass and species composition at different spatial scales.

In four farms representative of the main agro-ecological regions of Belgium fourteen parcels were sampled using a combined method (handsorting after mustard extraction). Parcels in both grassland and arable land were studied. In each two or three paired sample plots (1 m²) were randomly chosen; these were further subdivided resulting in four or six 0.5 m² samples (subplots) per parcel. From these averages were obtained for earthworm numbers and biomass at both plot and parcel level. Ordination (DCA/PCA) was applied to both raw earthworm data and to a data matrix where unidentified juveniles were prorated.

Earthworm numbers ranged from 10 to 463 individuals per m², biomass varied between 3 and 186 g per m² and species numbers ranged from 1 to 7 per parcel. In general differences between subplots were small. Plots in the same parcel tended to be highly similar, but in some cases large dissimilarities were present, reflecting abiotic gradients and the clustered population structure of earthworm communities at the field scale. The largest differences were observed at the parcel level. The latter may be attributed to differences in land use.

Both in number of individuals and in biomass differences in earthworm populations increased from subplot to parcel level. Given the clustered spatial distribution of earthworms one could argue for more replicates at the plot level. However, as earthworm sampling techniques are labour intensive, the used method proved to be a reliable compromise between labour and interpretable results.

Influence of agricultural intensification on the earthworm community in arable farmland of North China Plain

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Two field experiments had been conducted in Huantai County, Shandong Province, east of China, with an effort to understand the impact of agricultural intensification on earthworm diversity and population density. In Experiment A, a former arable field was put back in production after lying fallow for the last 20 years. In Experiment B, a field was selected that has been subject to intense agricultural practices for the last 30 years. The main experimental variable was nutrient supply (N), which included various combinations of straw and organic inputs as well as chemical fertilizer application in a winter wheat and summer corn farming system. The results identified seven species of earthworms in the two experiments. Average earthworm populations in the high fertility soil (experiment B, 1.83% organic matter) were relatively abundant, with a population density of 83.83 indiv./m². *Aporrectae trapezoids* was the most dominant species. In the low fertility soils (experiment A, 1.43% organic matter) the population density was only 40.18 indiv./m². *Drawida gisti* was the most dominant species. The impact of chemical fertilizer on the earthworm population was found to depend on the amount of organic input. The earthworm density by treatment had the following ascending trend: Chemical fertilizer, Chemical fertilizer + Wheat Straw, Chemical Fertilizer + Wheat Straw + Corn Straw, Chemical Fertilizer + Wheat Straw + Corn Straw + Organic Fertilizer. The earthworm biomass decreased when the application of chemical fertilizer occurred without organic input. There was a negative correlation between chemical fertilizer and earthworm density at the beginning of the experiment while the return of corn straw was not conducted. Later, organic matter input reduced the negative effect of chemical fertilizer on earthworm population.

Key words: earthworm community, agricultural intensification; arable farmland, China

SESSION 8

Autecology and Biology of Soil Animals

POSTER CONTRIBUTIONS

Why should soil insects be aggressive?

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Population regulation of the tipulid fly *Tipula paudosa* (leatherjackets) has long been assumed to be density independent larval mortality driven by weather patterns. Although there is evidence that different weather variables are important across the species range the predominant hypothesis is that shortage of rainfall in early development stages causes the population to crash. There is experimental evidence to substantiate this and a report on leatherjacket population fluctuations in south-west England also concluded that this was the case. However, the data presented show that whilst population crashes do occur when populations are high, a similar effect is not seen when populations are low. This raises the intriguing possibility that under harsh environmental conditions density-dependent effects may become important.

We postulate that this is driven by competition for favourable micro-habitat. There is evidence that leatherjackets are cannibalistic and our own observations have suggested that individual leatherjackets display different behaviours with some markedly aggressive and others passive. Thus we might conclude that the ‘aggressives’ would out-compete the others so that passive behaviours would disappear from the population over a number of generations. The existence of passive behaviours, in tipulids and other species, suggests that this is not the case and that a different explanation is needed.

There are many examples of context-specific behaviours in the literature, so we investigated the comparative dynamics of behaviourally structured and unstructured populations under harsh environmental conditions using mathematical models and numerical simulation. We show that a behaviourally structured population will persist longer under harsh environmental conditions and that there is an optimal proportion of aggressive individuals. A further conclusion is that persistence increases with greater numbers of behaviours. These models show that there can be an advantage to having a range of behaviours available within a population, and that such behaviours may not be adaptive in the Darwinian sense.

Influence of age in the reproductive success of the earthworm *Eisenia fetida*

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Ageing is usually defined as an increase in mortality and/or decline in fertility with advancing age, which includes not only reproductive success but also the quality of the offspring.

This paper investigates the influence of the age in the reproductive success of the simultaneous hermaphroditic species, *Eisenia fetida* (Oligochaeta: Lumbricidae). We also studied if *Eisenia fetida* has any kind of age-related assortative mating and we tested this through experimental crosses of earthworms of different age.

Earthworms used in this study were collected from a local stock population of *Eisenia fetida*. All the utilized specimens were virgins, incubated individually in Petri dishes from hatchlings and classified in two age classes: young earthworms (three months old) and old earthworms (two years old) and the following experimental crosses were set up: young x young (n=5), old x old (n=5) and young x old (n=9). The couples were housed in a Petri dish for a week to ensure copulation and after copulation, earthworms were isolated and thereafter their mass, the number of cocoons they produced, the hatching success and the number of hatchlings per cocoon were recorded weekly.

Cocoon production was not significantly affected by the age of the earthworms and a strong effect of age-related assortative was observed, i.e., the experimental crosses between individuals with the same age were more productive than the experimental crosses of earthworms with different age. This should implicate the existence of some mechanism of age-related mate choice in this species and further studies are necessary to verify this hypothesis.

Influence of inbreeding in the reproductive success of the earthworm *Eisenia andrei*

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Inbreeding refers to situations in which matings occur among relatives and to an increase in homozygosity associated with such matings and it is generally accepted that is unadaptive. Its deleterious effects, inbreeding depression, i.e. the reduction in fitness of offspring derived from mating between relatives compared to offspring resulting from mating among unrelated individuals, have been observed in many species.

Eisenia andrei (Oligochaeta: Lumbricidae) is an simultaneously hermaphroditic animal with reciprocal insemination, very prolific and that lives in very high densities, so very close inbreeding is expected.

In this study, we investigated the effect of inbreeding in the reproductive success of *E. andrei* and to test this we compared cocoon production and cocoon hatching in earthworm crosses with different degree of relatedness. We used five earthworm families consisting in four hatchlings from the same earthworm (brothers): all the earthworms were placed individually in Petri dishes until maturation and then the following experimental crosses were established: brother x brother (n=5), brother x earthworm of the same population (n=5) and brother x earthworm of other population (n=5). The couples were housed in a petri dish for a week to ensure copulation and after copulation, earthworms were isolated and thereafter their mass, the number of cocoons they produced, the hatching success and the number of hatchlings per cocoon were recorded weekly.

Cocoon production was significantly affected by the inbreeding and the lowest cocoon production was found in the crosses among brothers. The earthworm families showed different trends in response to the treatments and probably a larger sample size is necessary to corroborate this fact. The significance and importance of inbreeding in hermaphroditic animals living in limited spaces and very high densities are discussed.

Reproduction of *Hormogaster elisae* in the laboratory

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The factors influencing the reproduction of earthworms vary widely between species and populations (Lavelle & Spain 2001), but soil moisture, temperature, soil depth, and food resources are among the most important.

Some species of earthworm can be cultivated easily in the laboratory but others, such as *H. elisae*, are particularly difficult, and this can be a serious limiting factor for many experimental studies. The aim of this work was to achieve continuous laboratory reproduction of *H. elisae* and to determine the optimum conditions for this.

Microcosms were made with PVC cylinders (10 cm diameter, 30 cm deep) divided into three 10 cm sections representing different soil depths. These were filled with soil from the earthworms' place of origin (El Molar, Madrid), collected from depths of 0-10, 10-20 and 20-30 cm. All soil was sieved to 4 mm. Four earthworms with clitella were introduced into each microcosm. The microcosms were then subjected to 12 treatments combining different soil moisture levels (20% or 15%), two different temperatures (18°C or 13°C) and three cultivation times (15, 30 and 45 days). At the end of each experiment, the soil was sieved (by layer) through two meshes (2 and 2.8 mm) to collect the cocoons produced.

Hormogaster elisae reproduced stably and continuously in these experimental conditions, but overall the rate of cocoon production was very low (0.29 cocoons adult worm⁻¹ year⁻¹); their viability was low too (only 50% hatched). The process is therefore still not sufficiently optimised and needs to be further improved. More cocoons were produced at 15% soil moisture (67.05% of the total number produced in the entire experiment). No significant differences were found in cocoon production at 18° C and 13° C, but time to hatching was significantly different (90.59 days at 18°C and 132 at 15°C). Cocoons were preferentially deposited in the 10-20 layer (64.8% of the total number compared to 30.7% in the 20-30 cm layer, and 3.4% in the 0-10 cm layer).

New method of Marking Insect Species and biology, ecology and ethology of different species of the beetles (Coleoptera) in the southern Kazakhstan

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We propose practical utilization of new portable branding device, which weighs 1 kg and which can be used for marking numbers on the shell of insect. The numbers were made with white enamel or phosphorescent paint. In 1989-1990 marked population of *Synapsis tmolus*, *Copris hispanicus*, (Scarabeidae), *Cyphogenia gibba*, *Tentyrea gigas*, (Tenebrionidae), *Scarites busida*, (Carabidae) in the Chimkent region of southern Kazakhstan were studied. More than 1000 beetles were marked. Biology, ecology and ethology of these species of beetles were studied.

Life cycle of the earthworm *Octodrilus complanatus* (Oligochaeta, Lumbricidae)

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Earthworms are a widespread and diverse group of animals and account for the main part of the faunal biomass found in soil ecosystems. They act as key species of the decomposition processes and nutrient cycling. However, in spite of the high number of described species and their ecological importance, there is a lack of knowledge about the general biology and ecology of most earthworms. In the soil system, large-sized earthworm species play an important role in determining the soil structure and composition through their burrowing activity and surface cast deposition, both in natural and cultivated ecosystems.

The earthworm *Octodrilus complanatus* (Dugès, 1828) is a large-sized species often found in grasslands and pastures, with a wide distribution area in Europe and North Africa. In order to determine the characteristics of its life cycle, earthworms of this species were cultured from hatching until they reached maturity. Development rates, cocoon production and incubation period were recorded under controlled conditions. On average, individuals of *O. complanatus* reared in isolation from hatching reached maturity at day 150 and body weight at maturity ranged between 6 and 8 g. The cocoon incubation period was 66 days, and only one individual hatched from each cocoon.

The results showed that the life cycle of *O. complanatus* was characterized by both low growth rates and low fecundity. Specific features in life history traits of *O. complanatus* were compared with those of species of the genus *Octodrilus* and other related earthworms.

Role of the temperature in the reduction of the duration of the fallow of a ground contaminated by *Heterodera sacchari* and *Meloidogyne graminicola* (Heteroderidae)

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Soil temperature as a way to control nematodes without increasing fallow duration: case of rice culture contaminated by *Heterodera sacchari* and *Meloidogyne graminicola* (Heteroderidae)

Rice is the most important food crop in the world. It is a very versatile crop and there are many types of rice adapted to various environments and cultivation practices, which has a profound impact on plant parasitic nematodes and their concomitant damages. The nematodes *Meloidogyne graminicola* (Root knot nematode) and *Heterodera sacchari* (cysts nematode) belong to the family of Heteroderidae and cause a lot of damages to tropical rice crops. To control these parasites farmers may use chemicals but they are too expensive for the majority peasants of these developing countries. Using resistant varieties can be an effective solution but these varieties are not yet commercially available. Fallow appears as an effective solution, but three years and eighteen months of fallow are respectively needed to reduce enough the populations of *Heterodera sacchari* and *Meloidogyne graminicola*. Such fallows are often not bearable in dense human populations. The search for alternative control methods prompted this study, conducted in vitro, and in which we report the effect of temperature (30; 40; 45 and 50°C) on the mortality of the potential inoculums of both species. The study was conducted over a period of three weeks. The potential threshold or cumulative effect of temperature was tested. A temperature of 45°C or 50°C seems to allow for a strong reduction in fallow duration. 45°C seems to be a more realistic value easily reachable in the field if a dark film is laid on soil surface. The fact that increasing temperature had a significant effect either when temperature was constantly high or when it was lowered during the night suggests that such a temperature increases significantly nematode mortality as soon as the threshold of 45°C has been reached.

Effects of protein addition on enchytraeid reproduction in a sod-podzol soil

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Animals require additional protein volumes during reproducing period. It is a well known for different animal groups but not for soil oligochaets. We determine experimentally to what extent an increase of protein sources in soil stimulates enchytraeid reproduction.

Enchytraeus crypticus was chosen, as a test organism. A sod-podzol soil from Central Russia was used as a substrate. Three proteins were taken for the experiment: bacterial peptone, gelatin and bovine albumin. The soil was sieved (2-mm mesh) and mixed with a protein in the following concentrations: 1.8, 3.2, 5.6 and 10.0 mg/g dwt. Soil without protein addition was used as a reference substrate. Prepared substrates were put into experimental jars (10 g of substrate per jar) and were moistened until 60% of WHC. Each experimental concentration was replicated 4 times, and reference one - 8 times. Ten individuals of *E. crypticus* were placed in each jar. The jars were stored at 20°C for 4 weeks. Two weeks after experiment beginning, adult enchytraeids were removed to estimate their survival. Two weeks later, 10 ml of alcohol and few drops of 1%-bengalrose solution were added in every jar. The jars were stored for 24 hours and then juveniles were counted. Statistical analysis was performed with Statgraphics for Windows Plus 3.0 package.

After two weeks of the experiment, 95% of adult enchytraeids survived at any concentration of any protein used. The number of juveniles in the reference substrate was very low. Animals bred hardly at initial concentration of bacterial peptone and gelatin equal to 1mg/g while albumin induced a sharp increase of breeding at the same concentration. Bovine albumin stimulated enchytraeid reproduction to a greater extent than gelatin and bacterial peptone. Maximal number of juvenile enchytraeids was found in soil with initial protein concentration of 1.8 and 3.2 mg/g. Number of juveniles decreased drastically at initial concentration 5.6 mg of any protein per 1 g of soil and juveniles were practically absent at the concentration of 10 mg/g of any protein.

Low breeding rate of enchytraeids in the reference substrate was probably caused by lack of nutrients proteins in the sod-podzol soil. Protein addition compensates the lack of the nutrients and stimulates enchytraeid breeding. It appears that such fungivore animals as enchytraeids are capable to use more successful animal proteins such as bovine albumin in the comparison with bacterial pepton. Nonetheless high concentrations of proteins in soil depress enchytraeid breeding possibly due to forming of potentially toxic compounds during protein decomposition

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Comparison of growth and reproduction between two generations of *Eisenia andrei* inhabiting in artificial contaminated soils. First results.

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The aim of this study was to compare growth and reproduction of two generations of *Eisenia andrei* reared in artificial contaminated soils.

Mature worms (parents) were cultivated in artificial soils containing four heavy metals separately and in combinations of two, with 200, 300, 100 and 800 ppm of Cd, Cu, Ni and Pb respectively, during 60 days. Dried, ground and weighted horse manure was given weekly as food supplement. Control of number of cocoons produced and changes in weight were made every two weeks.

Once obtained F1, juveniles were transferred to parental soil and percentage of survivors, weight, time of maturation, cocoon production and hatching were recorded every two weeks.

For parental worms, the results show differences among treatments, obtaining in general the lowest number of cocoons per mature worm and number of hatchings and the highest percentage of failure cocoons in those involving Cadmium.

Initial results for F1 show a similar survival, time of maturation and number of cocoons in all treatments except for worms reared in soils with Cadmium, with a clear delayed maturation.

For the rest of treatments similar tendencies have been found between parental and F1 generations

Growth of *Hormogaster elisae*, *Allolobophora caliginosa* and *Allolobophora rosea* in three types of soil

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A peculiar distribution of earthworms has been recorded at El Molar (Madrid). The three most abundant species, *Hormogaster elisae*, *Allolobophora caliginosa* and *Allolobophora rosea*, show an aggregate-type distribution over three relatively isolated areas. *Hormogaster elisae* is the only species in the more sandy areas poor in organic matter, while *A. caliginosa* and *A. rosea* are found in soils where smaller size particles and higher carbon contents predominate. The aim of this study was to determine whether soil type actually influences earthworm distribution by studying the growth of these three species in three types of soil – that from the *H. elisae*, *A. caliginosa* and *A. rosea* areas - in the laboratory.

Each species was cultivated separately in the three types of soil for two months. The soil was changed every 14 days. At each soil change, the worms were weighed and their maturity assessed. The soil was checked for cocoons by washing it through a sieve column.

Hormogaster elisae grew best in the soil of the *A. caliginosa* area, and *A. caliginosa* and *A. rosea* grew best in the soil of the *A. rosea* area. These results contradict the distribution of the species observed in the field since in the natural environment *H. elisae* is not found, or is only found very sporadically, in the *A. caliginosa* area. Similarly *A. caliginosa* is not found in the area occupied by *A. rosea*. The only species that reached sexual maturity was *A. caliginosa*, which produced the fewest cocoons in the soil collected from the *H. elisae* area.

To understand why these species are not found at the field in the soils where they grew best in the laboratory experiments, competition studies are underway as well as experiments on the relationships between species distribution and soil's physical and chemical characteristics.

Investigation on the location and stability of cholinesterases in earthworms to validate its activity as a efficient biomarker

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In order to validate cholinesterases activity as biomarker, we are investigating the sensitivity of this biomarker earthworms collected in unpolluted fields (abandoned orchards). We first investigated the ChE activity level in five different species: *L. terrestris* (epi-anecic), *L. castaneus* (epigeic), *A. nocturna* (anecic), *A. caliginosa* and *A. chlorotica* (endogeic). Worms were collected at different seasons (spring, summer and winter) in 3 orchards. The results indicate that whatever the period of the year and the orchard under consideration the initial level of ChE specific activity is very stable for a considered specie but also between the anecic and endogeic species ($2,28 \pm 0,39 \text{u.mg}^{-1}$; $2,15 \pm 0,48 \text{u.mg}^{-1}$; $3,06 \pm 0,49 \text{u.mg}^{-1}$ for *A. caliginosa*; *A. chlorotica* and *A. nocturna* respectively). Moreover, both *L. terrestris* and *L. castaneus* exhibited a two to four fold higher activity than the others for a same level of protein contents which considerably enhances the specific activity of the ChE (respectively $5,93 \pm 0,93 \text{u.mg}^{-1}$ and $9,02 \pm 0,49 \text{u.mg}^{-1}$). This stability of the base level makes ChE activity a useful biomarker for the monitoring of pesticide effects under natural conditions.

In a second experiment we wanted to study the cholinesterase locations in the earthworms. We compared the activity level in different anatomic parts of the earthworm, especially in crop/gizzard and nervous tissue for three species. Obviously, the major part of the total ChE activity is found in the nervous tissue whereas the crop/gizzard activity is weak. All the biochemical studies are then carried out on extractions prepared from the whole animal which exhibits a better yield.

Finally we also investigated the structural and kinetics properties of the ChE. In regard to our previous results, it seems that the ChE is likely an acetylcholinesterase (AChE) since it hydrolysed acetylthiocholine at a higher rate than other substrate and was inhibited by eserine but not (or very weakly) by iso-OMPA, especially for the ChE of *L. terrestris*. The structural properties under investigations are compared with those of other invertebrates ChEs.

Internal regulation of reproduction seasonality in earthworm *Dendrobaena octaedra*

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Earthworms are semi-continuous breeders, producing ova at most times in the year while cocoons can be produced at any time of the year. However, the cocoon production in the field or in a culture depends on environmental conditions. Temperature, soil moisture, food supply and some other conditions are responsible for seasonal changes in cocoon production. In northern hemisphere the cocoon production is the highest in spring and early summer and reduced or stopped in winter months. The study on adult individuals of *D. octaedra* collected in 1995 in forests suggested that animals cultured in constant conditions exhibit seasonality of reproduction. In June 1996 adult individuals of *D. octaedra* (P generation) were collected in mixed oak-pine forests. To establish F1 generation cocoons laid in laboratory culture by parent generation were collected and placed in containers with soil. The medium for earthworms culture was artificial soil (OECD 207) consisted of: sand, sphagnum peat, kaolinite clay and calcium carbonate. The moisture content of the soil was adjusted to 40% of the dry weight of the basic substrate. Food source for earthworms was dry, powdered cattle dung. The containers were kept at temperature $15\pm 0.5^{\circ}\text{C}$, air humidity 80% and constant artificial light of low intensity. Every month during 47 months of culture the animals and cocoons were removed from the soil by washing on the sieve, weighed and replaced into new soil. Both P and F1 generations were kept in constant conditions throughout whole experiment. Despite of that individuals of F1 generation exhibited seasonality of reproduction. Reproduction was the highest in spring and summer and dropped in winter. Seasonality was noticeable in the fraction of animals reproducing and in the number of cocoons produced. Observed seasonal changes in cocoon production of F1 generation cultured in constant conditions suggest that an internal regulation of reproduction may exist in earthworm *D. octaedra*.

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Food selection by *Hormogaster elisae* (Oligochaeta, Hormogastridae) in laboratory cultures

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Several laboratory experiments are currently underway to study the influence of *Hormogaster elisae* Álvarez (1977), an endogeic species of semiarid Mediterranean areas, on soil organic matter dynamics. The first step is the study of the feeding processes of this species to determine whether it selectively consumes certain organic fractions of the soil. This would reveal the fraction most affected by its presence.

Hormogaster elisae specimens were cultivated for one week in microcosms containing soil from their area of origin, El Molar (Madrid). The superficial casts produced were removed every day. When the experimental period was over, the non-ingested soil (soil which had been in contact with the worm but had not been ingested) was separated from the deep casts. Non-ingested soil, casts and control soil were fractionated chemically (to obtain humic substances) and physically (without destroying the organic matter).

The results show that *H. elisae* actively selects the less humified organic material, i.e. the least degraded organic components. In the chemical fractionation, this material was represented by the 'free organic matter' and 'free fulvic acids' fractions. In the physical fractionation it was represented by the fraction > 50 µm.

In a second experiment, the earthworms were cultivated in soil of different textures (sieved to 4, 2 and 0.6 mm). Casts, non-ingested soil and control soil were removed from the microcosms and a particle-size separation with destruction of the organic matter was made. The results show that *H. elisae* positively selects the smallest fractions, especially clays, and negatively selects mineral particles > 250 µm. Such selection is less intense in soils rich in small particle fractions. Comparison of the results obtained by physical fractionation (without destruction of the organic matter) with those of particle-size separation (with destruction of organic matter) shows that casts contain a higher percentage of fine sands but less coarse sand.

A soil population of *Glomeris marginata* (Villers, 1789) in a Mediterranean forest (Diplopoda, Glomerida)

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A quantification of density and biomass of soil macroarthropods was conducted in a sclerophyllous forest of Mediterranean climate consisting mainly of *Quercus ilex* and *Pinus halepensis*. Field sampling was performed during 24 consecutive months in an experimental plot (40 x 40 m) placed at 860 m of altitude in the Parc Natural de Sant Llorenç de Munt (Barcelona, Spain, UTM coordinates 31TDG1411). Three soil horizons were sampled: L/F, H, and A (leaf litter fall, humus, and the first five cm of the mineral layer respectively).

A population of *Glomeris marginata* was found among the studied material. It presented a monthly mean density of $40.34 \pm 5.79 \text{ ind.m}^{-2}$, 61.1% of them corresponding to adult individuals and 38.9% to anamorphic larvae. The mean value of the sex ratio males: females was 1.33, although the mean monthly density value of males ($14.12 \pm 1.67 \text{ ind.m}^{-2}$) was not significantly higher than that of the females ($10.51 \pm 1.60 \text{ ind.m}^{-2}$).

Based on 105 individuals at different developmental stages, an estimate of individual biomass was performed. The biomass value (B) as fresh weight in mg was related to the width of the second segment in mm (t) through $B = 0.456 \cdot (t)^{3.189015}$ ($R^2 = 0.943$, $F=1719.4$, $p < 0.000$). Based on this equation, the average individual of the studied population showed a biomass value of $47.9 \pm 2.3 \text{ mg}$ (fresh weight).

The monthly mean population biomass was $1944.1 \pm 237.1 \text{ mg.m}^{-2}$, 96.96% of it corresponding to adult individuals (51.23% for females and 45.73% for males) and 3.03% to anamorphic larvae. No significant differences were found between adult males and females.

G. marginata occurred in all of the sampled soil horizons. Significant differences were found between monthly mean densities and biomasses in the different soil horizons. The mean density and biomass values in horizon H ($26.65 \pm 3.93 \text{ ind.m}^{-2}$; $1300.2 \pm 184.6 \text{ mg.m}^{-2}$) were significantly higher than those in A ($9.79 \pm 2.31 \text{ ind.m}^{-2}$; $379.5 \pm 92.0 \text{ mg.m}^{-2}$) and L/F ($3.91 \pm 0.83 \text{ ind.m}^{-2}$; $264.4 \pm 64.7 \text{ mg.m}^{-2}$). The mean density value found in A was significantly higher than that in L/F. The mean value of the Usher coefficient during the 24 months of the study also indicated a preference for horizon H. Horizontally, the values of the Morisita index showed that *G. marginata* forms aggregates in each one of the studied horizons.

Molecular cloning of reproduction related genes from common earthworm *Eisenia fetida*

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Earthworms are generally hermaphroditic and have testes and ovaries in separate segments. In order to understand gonad-morphogenesis and reproduction mechanism in earthworms, we employed the molecular approach. cDNA libraries with 10⁶ independent clones were constructed from a common *Lumbricidae* earthworm, *Eisenia fetida*, of different developmental stages. We screened a gene with DM domain from this species using a DM consensus sequence as a probe. The genes with DM domain is known to function in sex-determination processes in various animals, and is found in *Doublesex* gene in *Drosophila* and *mab* (male-abnormal) gene in *C. elegans*. As a result, we isolated a gene coding partial DM domains, and two well-conserved AAA (ATPase-Associated with different cellular Activities) motifs. During the isolation of the full-length cDNA, another gene coding two AAA motifs was identified. Each of these two genes show approximately 80% and 60% homology to mammalian *vcp* (valosin-containing protein) or *Drosophila ter* (transitional endoplasmic reticulum ATPase); thus, named *e-vcp-1* and *e-vcp-2*, respectively. Mammalian *vcp* is involved in a variety of cellular function including germ cell development and meiosis. *Drosophila ter* plays a role in the fusion of Golgi membrane and the degradation of endoplasmic reticulum-associated proteins. Recently, it was reported that during capacitation, human VCP phosphorylates on tyrosine residue(s), possibly in the C-terminal region and translocates from the neck to the anterior head (J. Biol. Chem. 278:11579, 2003). A tyrosine residue is present in the C-terminal region of *e-vcp-1*, but not in *e-vcp-2*. Reverse transcription-polymerase chain reaction (RT-PCR) analyses revealed that *e-vcp-1*, which had higher homology to mammalian *vcp* than *e-vcp-2*, is ubiquitously expressed in all segments from immature to mature worms. On the contrary, *e-vcp-2* is specifically expressed in the anterior segments of mature worms where gonads are located. No signal was detected in immature worms without clitella. Our *in situ* hybridization analysis clearly demonstrated the *e-vcp-2* gene expression in seminal vesicles where spermatogenesis takes place. The expression was associated with immature sperm. In human, RT-PCR analysis using multi-tissue cDNA panel revealed that human VCP is solely expressed in mature testes. Taken together, these findings suggest that *e-vcp-2*, a member of the AAA family ATPase in the earthworm, participates in some process of spermatogenesis.

Size-dependent sex allocation and size-related mate choice in the earthworm *Eisenia andrei*

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Although the biology and the life cycle of *Eisenia andrei* are well documented, many aspects of the reproduction and mating behaviour of this earthworm species remain poorly understood. In this study, we focused on body size as a possible trait that influence earthworm reproduction and mating processes. *E. andrei* is an simultaneously hermaphroditic animal with reciprocal insemination and many hermaphrodites are expected to mate not primarily to get their own eggs fertilized, but rather to get the opportunity to fertilize the eggs of their partners.

In the first part of the study, we investigated if *E. andrei* has a size-dependent sex allocation, i.e. if larger earthworms are more biased toward female allocation and produce more egg mass. To test this, we compared cocoon production between pairs of equal size and different size. Mature individuals of *E. andrei* were classified in two size classes (small and large) and housed in couples for a week. The experimental crosses were: large x large (n=8), small x small (n=8) and large x small (n=16). After copulation, earthworms were isolated and thereafter their mass, the number of cocoons they produced, the hatching success and the number of hatchlings per cocoon were recorded weekly.

In the second part we studied if *E. andrei* has a size-related mate choice and we tested this experimentally by studying the reaction and the mating preferences of focal earthworms of different sizes (small and large) to a compartment containing two potential mating partners, one small and one large (n=30).

The relationships between these processes and their evolutionary advantages in hermaphrodites are discussed.

Geographic parthenogenesis: *Eisenia nordenskioldi* case

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Eisenia nordenskioldi (Eisen, 1879) (Lumbricidae: Oligochaeta) is one of the most widespread Palearctic earthworms. Caryological analysis of the populations of this species shows that the extreme northern, north-eastern, western, south-western and southern parts of *E. nordenskioldi* range are populated by its polyploid (4 \times , 6 \times , 8 \times) amphimictic races while the extreme southern race (7 \times) is parthenogenetic. Thus we come across the "inverted" "geographical parthenogenesis" which in its classic Vandel's form suggests that parthenogenetic forms tend to occupy northern parts of a species' range.

Temperature factors influencing worm reproduction and growth

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Temperature had marked effects on the reproduction and growth processes of *E. fetida* under controlled laboratory conditions. The optimum temperature for worm reproduction was in the range 22-25 °C, especially at 25 °C, 1.92 days was required to produce each cocoon; 21.2 days was required for cocoon incubation; cocoon viability was over 85%; reproduction success was greatest (7.17 juveniles/worm/week).

The optimum temperature for worm growth was at 18 °C at which the growth rate reached 72 mg/worm /week in the incubation period. But cocoon production was lowest at this temperature. Worm growth was negatively correlated with cocoon production. Biomass gain during incubation mainly appeared in the earliest 3 weeks of the whole incubation period. The growth rate of hatchlings was highest also at 18 °C. The growth curve, is logistic, 90 days after emergence from cocoons, growth rate of *E. fetida* was visibly reduced. In this experiment, survival rate of *E. fetida* went beyond 80%. Lower temperature was good for survival of hatchlings. Survival rate in 30 days can act as an important parameter for reproduction success, which was positively correlated with the adult survival rate at 120 days. 50% of the worms became clitella between the ages 4 to 6 weeks, higher temperature led to earlier onset of sexual maturity.

Cocoon production and biomass gain can be considered to be two processes of energy allocation in total biomass production. It may be impossible to take both processes to high levels due to the negative correlation between worm growth and cocoon production.

However, some ecological factors maybe change the distribution of earthworm's energy between these two processes, which can make directive worm production (e.g. cocoon production or mass production) feasible. From this study it can be concluded that temperature differences exerted different influences on worm growth and cocoon production.

What supports earthworm development: nutrients or microbes in substrate?

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Substrata had a marked affect on population development and biomass gain of *E. fetida* in vermicomposting. Both in field and laboratory, *E. fetida* prefers to dwell in fermented cattle dung or a plant material-cow dung mixture fermented under aerobiosis over 15 days, with both high reproduction and growth rates. However, unfermented animal manures and human excrement were not suitable directly for vermiculture.

In mixtures of cattle dung with plant materials, the addition of fungus residue was most beneficial to both reproduction and biomass increase by *E. fetida*; sawdust more to worm reproduction, fruit by-products more to worm biomass gain.

A mixture of cattle dung and wheat straw in the ratio 7: 3 supported the highest reproduction rate and greatest mass increase by *E. fetida*, however, its support of worm reproduction was more statistically significant. Most plant materials with animal manures fermented over 15 days under aerobiosis were considered to be good worm substrate with high nutritional value and utilization, but the fermenting period could be accommodated to seasonal temperatures and plant textures.

Lower reproduction rate and mass increase were recorded in worm beddings with particles over 10.0 mm in size; particle sizes between 0.2 and 1.0 mm may be well useful for either substrate ventilation or worm digestion although pulverized substrate with particle size < 0.2 mm was more suitable to weight gain in juveniles.

Plant leaves, with lower lignin and cellulose content, support fast worm population development, but maintain it for a shorter period than plant stems and roots. There are no significantly regressive relationships between worm population development and lignin and cellulose content of plant materials. Corn roots and wheat roots, containing higher lignin and cellulose than their stems, produced greater population development and biomass increase by *E. fetida* compared with their stems with "high" nutritional value. The reason for this improvement function, probably relate to substance(s) from root excretions, has been not yet clear.

Comparative ecology of earthworm populations

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In the natural ecosystem, the species composition, abundance and biomass of earthworm population, apparently were influenced by vegetation and soil types, and varied essentially in relation to soil organic matter content and anthropogenic actions, and soil temperature, moisture and pH value. Some optimum ecological factors for worm growth are not best for worm reproduction, for instance, temperature 25 °C, moisture 70% and pH 6 are most suitable for *E. fetida* to cocoon production, while temperature 18 °C, substrate moisture 65% and pH 8-9 are most suitable to increase body weight.

In cultivated fields, most earthworms live within a 20 cm depth tillage layer due to the presence of rich nutritional elements and favorable pH value; whereas in artificial substrate *E. fetida* can descend to the 70 cm depth, or even deeper, owing to even-distributed nutrients and uniform feed texture. But 99.2% of earthworms dwelled within the first 50 cm depth of substrate. It was suggested that the substrate layer could be extended to a 50 cm depth.

Vertical distribution of earthworms was related to population density. It was difficult to compare living space between individuals in nature because of lower density of worm population and impracticality of accurate measurement. In fact, earthworms mainly concentrated on the upper soil layer, whereas in substrate, when the spatial competition between worm individuals intensifies with population density increase, worms tend to go down to lower substrate layers. There may exist a lower threshold density of ca. 60,000 ± 10,000 ind/m², over which earthworm migration would occur.

Whether in natural soils or in substrate, most earthworm cocoons were deposited in the upper 15 cm layer; this characteristic possibly evolves over a long period of time. Worms, however, dwelled in deeper layer in most time, which may be termed "non-uniformity of egg-laying and living in vertical space". A depth of 15-20 cm may be sufficient for breeding worms.

Under those experimental conditions the clitella of *E. fetida* appeared 60-70 days after cocoon appearance. The maximum individual weight was reached between 90-100 days. The worm density was not relative to the time in which earthworms start to breed or individuals were harvested.

E. fetida is a species of higher reproduction rate and fast-growth. It may be more favorable to rear cocoon-laying and body-fattening worms in different worm beds on the basis of the characteristics of *E. fetida* mentioned above.

On the base of substrate preference and vermiculture needs, the earthworms can be grouped in compost-preferring species and soil-preferring species.

Key words: Earthworm; Cocoon; Vertical distribution; Natural ecosystem, Substrate

SPECIAL SESSION

Invasive Earthworms

ORAL CONTRIBUTIONS

Nitrogen release from surface and incorporated plant residues by earthworms (Lumbricidae) in four soil types in southern Australia

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Two endogeic earthworms, *Aporrectodea rosea* and *A. trapezoides* (Lumbricidae), occur in soils used for grain production in southern Australia. An initial glass-house experiment evaluated the influence of *A. rosea* and *A. trapezoides* on the release and availability of nitrogen (N) in a red-brown earth soil. This soil had been treated with subterranean clover or wheat residues (both either added to the soil surface or mixed through the soil at the start of the experiment), wheat residues incorporated into the soil five years earlier, or no residue amendment (control). After four weeks, *A. trapezoides* increased soil inorganic N in the presence of surface-applied sub-clover residues, but *A. rosea* did not. Incorporation of sub-clover residues further increased soil N in the presence of *A. trapezoides*, but not *A. rosea*. Wheat residues immobilised N when incorporated, but *A. trapezoides* reduced this immobilisation. *A. rosea* did not. No earthworm effects were detected in the control and old wheat residue treatments.

A second glass-house experiment, run for nine weeks, investigated the influence of *A. trapezoides* (only) on the availability of N when sub-clover and wheat residues (surface and incorporated) were added to four different soil types: the same red-brown earth, a clayey red-brown earth, a grey mallee sand and a mallee sandy loam. A no residue amendment (control) was also run. In all treatments (residues and soil types), *A. trapezoides* increased the availability of N in the soil. Most N was released in the presence of sub-clover residues, in particular where it was incorporated. N was immobilised when wheat residues were incorporated, but *A. trapezoides* reduced this immobilisation. This work suggested that *A. trapezoides* has general potential to significantly increase the availability of N in soils commonly used for grain production across southern Australia.

The survival and biomass of earthworms varied between soil types and amendments. Most notably, the biomass of individual *A. trapezoides* was greater in the presence of sub-clover (probably better quality food) and when in mixed culture with *A. rosea* (effectively a reduction in the density of *A. trapezoides*).

Effects of earthworm invasion into ecosystems devoid of earthworms

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Mary Ann MCLEAN, Dennis PARKINSON

Exotic earthworm invasion has been studied in previously worm-free temperate forests dominated by *Acer*, *Betula*, *Pinus*, *Populus*, and *Quercus*. Invasion leads to significant changes in soil structure and function. Earthworms speed up the rate of forest floor litter decomposition and reduce thickness of the litter layer. C from the litter layer is redistributed into deeper horizons of the soil profile, and total C generally declines. Earthworm impacts on soil nutrient cycling vary with parent material and structure, land use history and species of invading earthworms. Reduced availability of N and P in soil horizons where most fine roots are concentrated, and increased leaching of these nutrients has been reported in some forests. Earthworms may also increase the bulk density and decrease water infiltration of forest soils. Some species such as *Lumbricus rubellus* and *L. terrestris* have larger impacts than other species.

Earthworm invasion also strongly influences the indigenous soil biota, microbial biomass, and respiration. The activities of *Dendrobaena octaedra* in pine forest organic layers tend to decrease microbial biomass, respiration and $q\text{CO}_2$. In aspen forest microbial biomass and respiration tend to decrease in the presence of *L. terrestris* and *Octolasion tyrtaeum*. Early in the invasion by *D. octaedra* the number of fungal isolates per particle (a measure of competition between fungi), first increased, possibly due to increased nutrients or spatial heterogeneity, then decreased as the organic layers became completely homogenized. Later in the invasion fungal community diversity and richness decreased and fungal dominance increased, apparently due to the disruption of hyphae. Disruption of fungal mycelium may be the cause of decreased arbuscular mycorrhizal colonization rates and total abundance in the presence of earthworms.

The fauna of forest soils previously devoid of earthworms is dominated by mesofauna which are detrimentally affected by the earthworms' burrowing and mixing activity. Although intermediate disturbance by the earthworm *D. octaedra* tended to increase microarthropod abundance, high biomass of this earthworm species or the presence of *O. tyrtaeum*, *Aporrectodea caliginosa* and *L. terrestris* reduce diversity and species richness of oribatid mites as well as abundance throughout all microarthropod taxa. Bioturbation resulting in disappearance of litter habitats, decreasing food quality, and mechanical disturbance, and the competition for food between earthworms and microarthropods are the two main factors endangering microarthropod communities in North American forests. Studies on vertebrate soil fauna, however, reveal that earthworm predators such as salamanders profit from the introduced food source in the short term.

Multiple changes to soil structure caused by earthworm invasion provide a dramatically different environment for plants than worm-free forests. A thinner litter layer after invasion changes the seedbed conditions to favor germination and survival of a different suite of species, including small-seeded plant species that do poorly on thick litter. Some forest herbs such as *Aralia racemosa*, *Trillium ssp.*, and *Uvularia grandiflora* are reduced in abundance during invasion. Reductions in plant species richness of 20-25% have been reported during invasion. Recovery of plant species after invasion depends on interactions with soil processes and herbivores, and may vary from none to complete recovery. Some rare species, such as the fern *Botrychium mormo*, are unable to survive loss of the litter layer and may not recover.

Earthworm invasion causes so many changes in ecosystem function, that it is likely to alter competitive relationships among plant species, possibly leading to changes in composition and successional trajectory. Earthworms may also facilitate invasion by exotic plant species such as *Rhamnus cathartica* into North American forests. Changes in soil nutrient dynamics, decomposer and plant communities and vertebrate foraging strategies imply that the below-ground invasion will dramatically alter the above-ground food web.

Effects of earthworm invasion into ecosystems inhabited by native earthworms

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The most conspicuous biological invasions in terrestrial ecosystems have been by exotic plants, insects and vertebrates. Invasions by exotic earthworms, although not as well studied, may be increasing with global commerce in agriculture, waste management and bioremediation. A number of cases have been documented in which invasive earthworms have caused significant changes in soil profiles, nutrient and organic matter dynamics, other soil organisms or plant communities. Most of these cases are in areas that have been disturbed (e.g., agricultural systems) or were previously devoid of earthworms (e.g., north of Pleistocene glacial margins). It is not clear that such effects are common in ecosystems inhabited by native earthworms, especially where soils are undisturbed. We hypothesize that indigenous earthworm fauna and/or characteristics of their native habitats may resist invasion by exotic earthworms and thereby reduce the impact of exotic species on soil processes. We will review data and case studies from temperate and tropical regions in order to test this idea.

Specifically, we will address the following questions: Is disturbance a prerequisite to invasion by exotic earthworms? If so, is the effect of disturbance a matter of degree (i.e., a gradient effect); does it change over a stepwise threshold; are some classes of disturbance more influential than others? What are the mechanisms by which exotic earthworms may succeed or fail to invade habitats occupied by native earthworms? Potential mechanisms could include 1) intensity of propagule pressure (how frequently and at what densities have exotic species been introduced and has there been adequate time for proliferation?); 2) extent of habitat matching (once introduced, are exotic species faced with unsuitable habitat conditions, unavailable resources, or unsuited feeding strategies?); and 3) degree of biotic resistance (once introduced into an otherwise suitable habitat, are exotic species exposed to biological barriers such as selective predation or parasitism, “unfamiliar” microflora, or effective competition by resident native species?). Once established, do exotic species co-exist with native species, or are the natives eventually excluded? Do exotic species impact soil processes differently in the presence or absence of native species?

SPECIAL SESSION

Invasive Earthworms

POSTER CONTRIBUTIONS

Cosmopolitan earthworms as invasive species? A global and historical perspective

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Reliably distinguishing between the native and the exotic components of an earthworm community is crucial for understanding biodiversity and ecosystem functioning. This most recent report culminates 15 years of field and literature survey of the global fauna that has resulted in description of about 250 new natives and discovery of first instances in particular regions of 32 exotics. From a Worldwide pool of about 5,000 described taxa, just 111 are commonly encountered outside of their endemic domains. These 'cosmopolitan species' comprise approximately 47 Megascolecidae drawn mainly from the 808 Asiatic pheretimoids, 33 from a total of 666 holarctic Lumbricidae, and 31 species from the other 18 earthworm families such as Moniligastridae, Acanthodrilidae and Octochaetidae. Examples of comparative diversities are: around 416 species from mainland Australia (ca. 16% exotics) and another 232 from Tasmania (ca. 12% exotics); 200 species from New Zealand (ca. 14% exotics); 160 from North America (33% exotic); 150 from mainland China and Hainan (27% exotics); 87 from Japan and the Ryukus (ca. 50% exotic); 80 species from Korea and Quelpart Island (24% exotics); 55 species from Taiwan (44% exotics); and 46 from Pacific Isles (63% exotics). Virtually isolated from global commerce until recent times, Australia, Tasmania and New Zealand have relatively low numbers of known exotics and the latter two are especially similar with 70% of these being Lumbricidae of direct or indirect European origin. In Japan, Korea, Taiwan, and southern China most of the ca. 24-60% exotics are due to exchanges of south-east Asian pheretimoids (ex *Pheretima* auct.), which tend to be especially prevalent on subtropical Ryuku Isles and Taiwan. Continental North America is intermediate yet more varied with about one third of its fauna exotic and half of these Lumbricidae introduced only in the last 1,000 years. Islands present special situations; for example, the earthworms of the British Isles (48 species), Hawaii (33 species), and Iceland (11 species) are mostly introduced/invasive. The situation in Madagascar is complicated by historic migrations of Asian settlers. Biodiversity differences for natives are accounted for by geological histories (e.g. plate tectonics, volcanism, glaciation) and by topographic and climatic factors, whereas occurrence of exotics most often echo patterns of human migration, and overall appreciation of both groups is yet determined by intensity of taxonomic treatment. Only rarely do exotic earthworms gain new lands via self-propelled or 'natural' processes, transportation in the main is human-mediated with species origins often corresponding to the origins of various agricultural crops. And, although earthworms are usually considered beneficial, or at worst benign, there are some reports of deleterious environmental effects. Modes of initial introduction are discussed in an historical context contrasted with recent quarantine barriers and deliberate rather than adventitious dispersion.

Keywords: Annelida: Oligochaeta, *Pheretima*, biodiversity, invasive, Australia, Asia, America, Europe.

Observations on the spread and distribution of the New Zealand flatworm (*Arthurdendyus triangulatus*) in pasture field in western Scotland

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The New Zealand flatworm is a terrestrial planarian which is an obligate nocturnal predator of earthworms in the British Isle where it was first recovered in the early 1960s. Since then it was found in the Faroe Islands but has not yet become established in continental Europe. Research in Scotland has implicated its presence with the eradication of moles (*Palpa europæana*) but its detrimental effect on the environment (soil processes etc) and on other forms of wildlife e.g. birds and animals which depend upon earthworms as a major constituent of their diet is unknown.

As a part of a study on the ecology of the New Zealand flatworm investigations were undertaken to ascertain its spatial distribution, rates of dispersion and relationship with earthworms in a 4.65ha pasture field. The spatial distribution of the flatworm in the field was investigated by putting out "traps" (60cm x 30cm polythene sacks filled with 6kg grit, under which the flatworm took refuge during the day) in a grid across the field. To study the rates of dispersion of the flatworm a part of the field was chosen where there were no flatworms and a number were placed under a "trap" which was at the centre of an X with "traps" placed at 1, 3, 6, 9, 12, 15, 18, 21 and 24m from the centre.

Results indicated that flatworms were not found throughout the field but restricted around its periphery where they had a significant negative relationship with earthworm numbers. They were found to disperse from the central "trap" to the 24m "trap" within 21 days and that this was associated with a reduction in numbers of earthworms around the central release "trap".

The results would suggest that the New Zealand flatworm could disperse by itself at over 1m per day under field conditions. The distribution of *A. triangulatus* in the field may be explained by it migrating out from the periphery of the field which gave it access to refugia during the winter and summer months when the temperature dropped below freezing or rose above 20°C. An alternative explanation could be that the centre of the field had a tendency to become waterlogged and that flatworms were absent from there as they could not tolerate this condition as well as earthworms.

Further research is required to ascertain if either of the above hypotheses is correct.

Policy and management responses to earthworm invasions

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The establishment and spread of earthworms not native to North America has been ongoing for centuries. These introductions have occurred across the continent and have had resulted in considerable modifications to ecosystem processes and to soil foodwebs. However, many areas remain that have never been colonized by earthworms, or that have soils still inhabited exclusively by native earthworm fauna. Although several modes of transport and subsequent introduction of non-native earthworms have been identified, little effort has been made to interrupt the flow of new species into new areas. Examples of major avenues for introduction of earthworms are the fish-bait industry, the horticulture industry, and the vermicomposting industry. In this paper we seek to identify methods by which the movement of earthworms and earthworm-containing media could be better regulated such that introduction of new species or introductions to new areas would be minimized. Additionally, we examine land management practices that influence the establishment of introduced species in several ecosystem types, and identify situations where land management may be useful in limiting the spread of introduced earthworm species.

Landscape patterns of earthworm invasion and understory plant composition in lakeside northern temperate hardwood forests

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Recent studies show that exotic earthworm invasion can significantly affect the understory plant communities and nutrient cycling in northern temperate hardwood forests. However, little is known about the extent and pattern of earthworm invasion in previously earthworm-free areas of the northern United States. We studied how earthworm distribution in lakeside mature *Acer-Betula* forests relates to probability of earthworm introduction, forest floor depth, and understory plant communities. We sampled earthworms, soils, and vegetation in 314 plots located in 40 mature *Acer-Betula* stands in two regions of the midwestern United States. Stands were comparable in tree composition, biomass, geology, and management history. We created an index of probability of earthworm introduction for each stand based on the density of cabins/resorts, boat landings, roads, and campsites. In both regions we found a relationship between exotic earthworm presence and this index. *Dendrobaena octaedra* was the only species found in the most remote plots. *Lumbricus rubellus*, the species most associated with the loss of the O_e/O_a horizons, was the most widespread species (>66% of the plots). Plots with all three earthworm ecological groups (epigeic, endogeic, anecic) had an average of 50% less sugar maple seedling cover and between 10 and 20% lower plant species richness than plots with few or no earthworms. Our results further support other studies showing that exotic earthworms can significantly alter the structure and composition of hardwood forest understory plant communities. This study is the first to show the spatial aspects of exotic earthworm invasion in the northern United States. We will use it to develop maps of potential exotic earthworm distribution in hardwood forests of this region.

Impact of earthworm invasion on microarthropod communities in Canadian aspen forest soils

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The last glaciation eradicated the native earthworm fauna of Canada. With the advent of European settlers earthworm species native to the old world started to invade North America. Since then earthworms have changed the structure of North American soils dramatically. Surprisingly little is known about the impact of this invasion on the indigenous soil fauna. In western Canada large areas still are free of European earthworms but rapid colonization has been documented during the last decades. The most rapidly spreading earthworm species include the epigeic *Dendrobaena octaedra* and the mineral soil dwelling *Aporrectodea caliginosa*, *Lumbricus terrestris*, and *Octolasion tyrtaeum*.

In the present study mineral soil dwelling species were used in field and laboratory experiments to study their effect on microarthropod communities in aspen forest soils near Calgary (Alberta; Canada). Generally, microarthropod groups were detrimentally affected by earthworm activity due to the processing of organic material and mixing of mineral soil with organic matter. The fact that earthworms, collembolans and oribatid mites feed on similar food resources led to competition for food resources. In comparison, densities of microarthropods in treatments with earthworms were similar in litter and earthworm casts, and in organic and mineral substrates, whereas abiotic and microbial properties of these substrates differed significantly. This indicates that in addition to earthworm-mediated changes in food availability and competition, microarthropods were affected directly by mechanical disturbances due to burrowing, feeding and casting of earthworms. Disturbance by earthworms was very strong in the laboratory systems leading almost to extinction of oribatid mites in treatments with two earthworm species.

Lumbricid earthworm invasion in new habitats in the Carpathians of Romania

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Recent field research and sampling of earthworms at sites studied approximately 25-30 years ago in the Carpathians, revealed significant changes in the earthworm community structure of several mountain habitats, induced by a process of invasion by peregrine lumbricid species. This process seems to be quite rapid and contemporary.

Thus, *Lumbricus terrestris*, and to some extent the large parthenogenetic form of *Octolasion lacteum*, invaded new habitats, replacing characteristic earthworm communities. These ubiquitous species, with wide ecological tolerances, have partly or totally replaced the local (mostly endemic) species which apparently have narrower tolerances.

Earthworm invasions were observed in seven different types of biotopes from the Carpathians in Romania. Comparative tables show the structure (relative abundance) of the original and now invaded earthworm communities. If this clear invasion happened in these places, it is probable that it has occurred or will occur also in other places. New field investigations and re-sampling in previously studied areas will be needed to confirm this phenomenon.

It is quite difficult to answer the question why this process happens, and which are the controlling factors or patterns. As a first approximation, it seems that in addition to the direct transportation of these species by human agricultural activity and clear cutting of forests, the invasion process is facilitated by a general disturbance of the environment by pollution. The use of pesticides, fertilizers and other polluting chemicals may first affect (or even eliminate) the endemic species with narrower ecological tolerances. The vigorous, ubiquitous forms, such as *L. terrestris* or the parthenogenetic form of *O. lacteum*, may then show a rapid adaptability to these new conditions.

The invasion and expansion of these ecologically vigorous species inside the European continent should be considered as a semi natural, human-induced process of changing original local faunas.

Author index

- Abbad Andaloussi S., 118, 119
Adl S., 16
Ainsworth G., 23
Aira M., 89, 133, 303
Alard D., 48
Alberton O., 240
Albertus R., 280
Aleksseeva T., 187
Alves Moreira J.A., 238
Alvinerie M., 261
Amato M., 319
Amorim M., 183
Andersen M.N., 245
Anderson A., 166
Andrade G., 61
Angeles A., 257
Arancon N.Q., 82, 192
Aranda E., 210
Arnold J., 90, 202
Arnold R.E., 201
Arrignon F., 17
Ash N., 143
Attignon S.E., 18, 91
Aubert M., 19, 32, 50
Azontonde A., 239
Baeté H., 233
Baker G., 83, 288, 319, 321
Bakonyi G., 103, 212, 234
Balík V., 13
Bally R., 94
Baoqing W., 296
Barois I., 25, 210, 235, 321
Barot S., 92, 111, 146
Barros E., 107
Barthès B., 239
Bastardie F., 236
Baudoin E., 94
Behan-Pelletier V., 20
Behera B., 143
Bellido A., 171
Belzunces L., 207, 308
Benito N.P., 21, 65, 240
Benoit P., 215
Berg M.P., 9, 229
Bernardes F.F., 24
Bernhard-Reversat F., 131
Bernoux M., 238
Bezemer M., 38
Bhattacharya S.S., 188
Bihn J., 264
Bihn J.H., 22
Binet F., 187, 223
Birch A.N.E., 228
Bityutskii N.P., 135
Black H.I.J., 23, 93
Black K.G., 157
Black S., 201
Blackshaw R.P., 95, 298
Blakemore R.J., 323
Blanc C., 154, 237
Blanchart E., 238, 239
Bloem J., 87, 102
Blouin M., 92
Boag B., 324
Bohlen P., 320
Boizard H., 194
Bolger T., 105
Boström S., 72
Bouché M.B., 179
Bousquet -Melou A., 261
Bousserrhine N., 118, 119
Brandão Jr O., 240
Brandl R., 22
Brennan A., 252
Breton V., 121
Briones M.J.I., 54, 156, 225
Brokaw J., 208
Brown D.J.F., 130
Brown G.G., 21, 24, 25, 44, 65, 112, 240
Brown V.K., 10
Brun J.-J., 121
Brussaard L., 87, 102
Brygoo Y., 140
Bueno-Villegas J., 25
Bureau F. 19, 32, 48, 49, 124
Bürkel M., 46
Butovskaya P.R., 241
Butovsky R.O., 241
Butt K.R., 33, 214, 242
Byrne D., 249
Byrne R., 82
Byzov B.A., 120, 135
Caballero M.E., 24
Cabrera G., 271
Cadet P., 149
Calhõa C.F., 268
Callaham Jr M.A. 243
Caner L., 121
Capowiez Y., 194, 207, 215, 236, 251, 308
Carral E., 244
Castaño-Meneses G., 263
Castro C.P., 268
Caul S., 228, 245
Cécillon L., 121
Chabert A., 94
Chamberlain P.M., 93
Chaney K., 281
Chaplow J.S., 23, 93
Chattopadhyay G.N., 188
Chauvat M., 84
Cilliers S.S., 106
Cluzeau D., 137, 171
Coleman D.C., 16, 85, 243
Connolly J., 105
Cook R., 169, 246
Cortet J., 94, 228, 245
Creamer R., 23
Crossley Jr D.A., 85
Csuzdi C., 12, 247, 255
Curmi P., 171, 238
Curry J.P., 166, 167, 248, 249
Damoff G., 321
Dauber J., 122, 136
Dawson L., 169, 246
Dawson R., 190
De Goede R.G.M., 87, 102, 109
De Los Angeles Martínez L.M., 59
De Vos B., 233
De Vries F.T., 87
Decaëns T., 4, 17, 19, 32, 36, 48, 49, 50, 51, 114, 124
Degteva S.V., 40
Del Castillo D., 107
Demarle O., 260
Demšar D., 250
Denoyelle R., 251
Desjardins T., 152
Devaux A., 251
Dias S., 268
Díaz Cosín D.J., 158, 159, 307, 310
Didden W.A.M., 185
Diouf M., 113
Djigal D., 154
Dmowska E., 191
Dominguez J. , 55, 89, 90, 123, 133, 202, 217, 299, 300, 303, 313
Donovan S.E., 95
Doumandji-Mitiche B., 58
Douzet J.M., 238
Dózsa-Farkas K., 254, 255
Drury C.F., 256
Duboisset A, 118
Dubs F., 252, 268
Duncan K., 208
Dutoit T., 253
Dyckmans J., 150, 157
Džeroski S., 250
Edwards C.A., 82, 180, 192
Eggleton P. , 34, 252
Eijsackers H., 80
El-Hadef El-Okki M., 193
Elhottová D., 195, 259
El-Mariami M.A., 54
Enami Y., 199, 289
Eschenbrenner V., 238
Faber J.H., 96, 102, 229
Fábián M., 103
Fadda S., 253
Farkas J., 26, 254, 255
Feijoo A.M., 27, 125
Feller C., 239

Fenton B., 130
 Ferreira A., 299, 300
 Filser J., 100
 Folgarait P.J., 152
 Forano C., 187
 Ford L., 208
 Förster B., 61, 97, 98, 226, 264
 Fountain M.T., 10
 Fourquim V.H., 24
 Fox C.A., 256, 267
 Foy N., 194
 Fragoso C., 27, 44, 62, 257, 258, 321
 Fraser T., 321
 Freitas M.H., 274
 Frelich L.E., 320, 326
 Frouz J., 126, 195, 259
 Futagami K., 177
 Gabriel E., 84
 Gago J.A., 303
 Gaillard H., 124
 Gaime I., 210
 Gama M.M., 268
 Gamou S., 28, 312
 Gange A., 169, 246
 García J.A., 235
 Garcia M.V.B., 57, 77, 97, 98, 226
 Garcia T., 98
 Garcin A., 260
 Garnier-Silam E., 140
 Garnier-Zarli E., 118
 Gauthier G., 261
 Genzer N., 29
 Geoffroy J.-J., 30
 Gers C., 261
 Giesemann A., 221, 286
 Gil R., 301, 307
 Gioia C., 4
 Girardin C., 239
 Gómez M., 123, 202
 Gongalsky K.B., 172, 227
 Gonzalez G., 321, 325
 Grayston S., 169, 246
 Gregory P., 170
 Griffiths B.S., 228, 245, 324
 Grimaldi M., 145
 Guo-kang C., 190
 Gutiérrez M., 158, 159
 Häggblom M.M., 174
 Haimi J., 196, 204, 252
 Hale C., 320, 325
 Hallaire V., 137
 Hampe V., 63
 Hanagarth W., 98
 Hang Y., 190
 Harry M., 119, 140
 Harsia T., 278
 Hasegawa Ma., 198
 Hasegawa Mo., 31
 Hashimoto M., 115, 160
 Hashimoto T., 67
 Hassall M., 53, 262
 Haydock, 281
 Hedde M., 19, 32, 49, 51, 124
 Hedlund K., 181
 Heemsbergen D.A., 229
 Heimbach F., 200
 Heinemeyer A., 225
 Helden A.J., 166
 Hendrix P.F., 85, 321
 Henegan L., 320, 327
 Henning Krogh P., 165, 245, 250
 Hermy M., 295
 Hernández P., 159, 301
 Hernández-Castellanos B., 25
 Hernández-Ruiz P., 263
 Hijii N., 37
 Hill P., 125
 Hirayama-Minagawa T., 28
 Hodson M.E., 201
 Höfer H., 22, 61, 98, 264, 285
 Hofmockel M., 243
 Hohberg K., 161
 Holdsworth A.R., 320, 326
 Holec M., 126
 Holmstrup M., 245
 Honda M., 28, 312
 Horwood J.A., 33
 Huerta E., 62, 265
 Hunter M., 16
 Hunter M.D., 85
 Hyodo F., 162
 Ilieva-Makulec K., 191, 266
 Ilmarinen K., 163, 164
 Ineson P., 225
 Ito M.T., 31, 115, 160, 177
 Ivits E., 252
 Iwasa M., 289
 Jackson K., 34
 James S., 321
 Jesús J.B., 158, 159, 301
 Jiao X., 270
 Jiménez J.J., 4, 35, 36, 114
 Jocteur-Monrozier L., 94
 Johnson S., 170
 Jones D., 252
 Joschko M., 267
 Jouquet P., 127, 136
 Juárez D., 258
 Jucevièa E., 52
 Juen A., 151
 Jufferholz T., 197
 Julka J.M., 143
 Juvy B., 121
 Kádár I., 212
 Kamitani T., 198
 Kaneda S., 199
 Kaneko N., 115, 132, 160, 177, 198
 Karasawa S., 37
 Kardol P., 38
 Kawachi K., 67
 Kawaguchi S., 128
 Kawasaki K., 28
 Keating A., 252, 268, 274
 Kerboua F., 193
 Kersanté A., 187, 223
 Ketoja E., 242
 Khomyakov N.V., 120
 Kirwan L., 105
 Kiss I., 103, 234
 Kitayama K., 31
 Kleinwächter M., 46
 Klompen H., 76
 Knott E., 196
 Kobeticová K., 284
 Kocourek J., 195
 Kolesnikova A.A., 39, 40
 Konaté S., 129, 162
 Korasaki V., 21
 Kostecka J., 7
 Krištufek V., 125
 Krivolutsky D.A., 41, 42, 43
 Krogh P.H., 228
 Krueck S., 267
 Kula C., 182, 200
 Kumar N.G., 269
 Kuperman R., 183
 Kusińska A., 144
 Lachat T., 18, 91
 Lachnicht S., 321, 325
 Ladd J.N., 319
 Lamandé M., 137
 Langdon C.J., 201
 Lanno R., 180, 183
 Laossi K.-R., 131
 Lapied E., 44, 45, 211
 Lapteva E.M., 40
 Larink O., 46
 Larsen J., 165
 Larsen T., 165, 250
 Lata J.-C., 127, 136
 Latipi Z., 262
 Laurikainen M., 196
 Lavelle P., 4, 36, 44, 62, 92, 111, 145, 146, 152, 162, 213, 231, 252, 268, 276, 282
 Lazarova S.S., 130
 Lazcano C., 123, 202
 Lebedeva N.V., 41
 Lebissonais Y., 124
 Lechelt-Kunze C., 203
 Lee S., 82
 Legendre S., 75
 Leitão P., 268
 Lemos M.F., 268
 Lepage M., 127, 129
 Li Q., 270
 Liang W., 270
 López Mosquera M.E., 244
 Loranger-Merciris G., 131

Luizão F., 107
 Lukkari T., 204
 Luz T., 268
 Ma W.-C., 185
 Maboeta M.S., 106, 205
 Mac Callaham Jr., 321, 325
 Maerz J.C., 209
 Magid J., 165
 Maksimova S., 206
 Malloch G., 130
 Mando A., 99
 Maraun M., 47, 230, 327
 Maraux F., 238
 Margerie P., 17, 19, 48, 49, 50, 51
 Mariño F., 306
 Marmonier P., 171
 Marques R., 22, 61, 264
 Martakis G.F.P., 96
 Martínez M.A., 271
 Martin-Laurent F., 223
 Martius C., 98
 Mascle O., 251
 Mateos E., 311
 Mathieu J., 141
 Mato S., 217
 Matsuda K., 115, 132
 Matsumoto S., 28, 312
 Matyukhin A.A., 302
 Matyukhin A.V., 42, 43, 302
 Mayzlish Einav, 104, 272
 Mazet B., 207
 Mazzia C., 207, 308
 Mboukou-Kimbatsa I., 273
 Mc Lean M.A., 320
 Mc Namara, 93
 Measey J., 11
 Méès L., 17
 Mehta C., 208
 Melecis V., 52, 283
 Melsa D.A., 209
 Mendes S., 274
 Messean A., 245
 Mestizo D., 210
 Meyer E., 176
 Miambi E., 113
 Migge S., 139, 209, 320, 327
 Mikola J., 163, 164
 Miksche D., 166, 167
 Milcu A., 86, 168
 Minette S., 238
 Minor M.A., 275
 Miquel C., 311
 Miyoshi N., 67, 199, 289
 Mizen T., 246
 Moënné-Loccoz Y., 94
 Monroy F., 89, 133, 303
 Mora P., 113, 119, 134, 211
 Moreira M., 244
 Moreno A.G., 252
 Moss A., 53
 Murray P., 169, 170, 246
 Muys B., 233, 295
 Nabil H., 304
 Nagel P., 18, 91
 Nagy P., 103, 212
 Nahmani J., 211, 213
 Nair G.A., 54
 Narimatsu M., 175
 Nazaret S., 94
 Neilson R., 130, 324
 Nel W., 280
 Nevo E., 247
 Nieminen M.A., 214, 242
 Niven S.J., 95
 Normand P., 237
 Nosek J.N., 103
 Nováková A., 138
 Nuutinen V., 214, 242
 Oba H., 198
 Olejniczak I., 266
 Olejnik A.S., 135
 Oliveira C.M.G., 130
 Oliveira L.J., 112
 Olvera-Velona A.R., 215
 Orgeas J., 253
 Ostle N., 93, 246
 Ouédraogo E., 99
 Pacholski A., 267
 Pączka G., 7
 Panchenko I.A., 101, 172, 305
 Pando A., 211
 Pani S.C., 143
 Panigrahi P.K., 143, 276
 Pardo E., 306
 Paris C., 136
 Parkinson D., 320, 327
 Partsch S., 86, 168
 Pashanasi B., 107
 Pasini A., 21, 65
 Pavlíček T., 12, 247
 Peijnenburg W.J.G.M., 185
 Pen-Mouratov S., 216, 220
 Pérès G., 137, 171
 Pérez D., 217
 Persson T., 101, 277
 Petrovskii S.V., 298
 Peveling R., 18, 91
 Pižl V., 13, 138, 259
 Plakht J., 29
 Platner C., 116, 173
 Plum N., 100
 Pokarzhevskii A.D., 66, 101, 172, 305
 Ponel P., 253
 Pop A.A., 55
 Pop V.V., 278, 328
 Popovici I., 278
 Pospiech N., 279, 290
 Posta K., 103
 Postma-Blaauw M.B., 87, 102
 Prasanna A.R., 269
 Purvis G., 166
 Qin X., 296
 Querner P., 56
 Quintero H., 27
 Rabeling C., 57, 77
 Rached O., 193
 Rachor I., 173
 Rakhleeva A.A., 73
 Ramajo M., 307, 310
 Ranganathan L.S., 222
 Ranjard L., 127, 136
 Rault M., 207, 251, 308
 Reich P.B., 326
 Reinecke A.J., 280
 Reinecke S.A., 280
 Remini L., 58
 Répási V., 103
 Reversat G., 304
 Richard G., 194
 Richter D.D., 243
 Richter K., 139
 Rickfelder T., 46
 Riepert F., 60
 Riou M., 211
 Rodrigues M.R.L., 98, 285
 Rodríguez Aragonés C., 59, 271
 Rodríguez M.T., 244
 Rodríguez M., 257
 Rojas P., 257, 258
 Romanova T.S., 73
 Römbke J., 60, 61, 98, 182, 183, 200, 226, 264
 Rommeler A., 122
 Roose Amsaleg C., 119, 140
 Rossi J.-P., 35, 62, 111, 134, 141, 146, 213
 Ross-Nickoll M., 293
 Rothwell A., 281
 Rouland C., 113, 134, 211
 Routray P.L., 143
 Roçen A., 218, 219, 291, 309
 Ruess L., 174
 Ruiz M.P., 307, 310
 Ruiz N., 231, 282
 Rusek J., 184
 Russell D., 63
 Saharaoui L., 58
 Sahli L., 193
 Sahu J., 143
 Sáinz M.J., 244
 Salamne I., 52, 283
 Salminen J., 196
 Sampedro L., 142
 Sanders D., 173
 Santos J., 274
 Sarda X., 238
 Saridakis G.P., 240
 Sarrazin M., 145
 Sasaki M., 199

Sasaki T., 177
 Sautter K.D., 64, 65
 Savin F.A., 66, 172
 Sawahata T., 175
 Schaefer M., 116, 139, 173, 197, 209
 Schaeffer A., 293
 Schallnaß H.-J., 97
 Scheidegger C., 252
 Scheu S., 47, 86, 108, 116, 153, 168, 174, 176, 230, 320, 327
 Scheuerer A., 63
 Schlaghamerský J., 284
 Schmelz R., 61
 Schmidt O., 150, 156, 157, 166, 167, 248, 249, 287
 Schmidt P., 98, 264, 285
 Schneider K., 230
 Schrader S., 157, 221, 286, 287
 Scopel E., 238
 Scown J., 288
 Scrimgeour C.M., 157, 166, 167
 Seeber J., 176
 Self P., 23
 Selonon S., 196
 Senapati B.K., 143, 276
 Seres A., 103
 Serra A., 311
 Seuge C., 134
 Shamir I., 104, 272
 Sheehan C., 105
 Shimano S., 67, 199, 289
 Shukurov N., 216, 220
 Sidorchuk E.A., 68
 Simmons B., 85
 Simón C., 69
 Sinsin B., 18, 91
 Sirén T., 242
 Skalski T., 279, 290
 Smant W., 38
 Smith J., 106
 Smrž J., 70
 Sobczyk Ł., 71, 291
 Sohlenius B., 72
 Soldati F., 260
 Soto P., 179
 Soulas G., 223
 Šourková M., 259
 Sousa J.P., 60, 69, 252, 268, 274
 Spaul V.W., 149
 St John M., 20
 Starý J., 13, 138
 Steinberger Y., 29, 104, 216, 220, 270, 272
 Sterenberg M., 272
 Sticht C., 221
 Stone L.F., 238
 Strenner A., 26
 Striganova B.R., 73
 Sublette K., 208
 Sugimoto A., 177
 Suzuki T., 28, 312
 Sy M., 154
 Szanser M., 144, 266
 Szathmary K., 26
 Szél G., 252
 Szira F., 234
 Taiti S., 262
 Tajovský K., 259, 292
 Takahashi T., 67
 Tapia-Coral S., 107
 Taskaeva A.A., 40
 Tato A., 90, 313
 Tayasu I., 152, 162
 Teno S., 204
 Theissen B., 293
 Theron P.D., 106
 Thoma G., 208
 Thomas F., 145, 146, 152
 Thompson J., 228, 245
 Thys S., 233
 Tiunov Alexei V., 139, 147, 153
 Todd T., 208
 Tondoh J.E., 74, 75, 162
 Török J., 254, 255
 Torres E., 240
 Tosza E., 218
 Toyota A., 115, 160
 Traugott M., 151
 Traunspurger W., 161
 Treonis A., 169, 246
 Trigo D., 158, 301, 310
 Tuf I.H., 294
 Tufová J., 294
 Uchida T., 177
 Ushanandhini N., 222
 Uvarov A.V., 108
 Väisänen A., 204
 Valckx J., 295
 Van De Heuvel H.H., 9
 Van Der Hout A., 96
 Van Der Putten W., 38
 Van Der Sluis T., 39
 Van Der Wal A., 38
 Van Der Zee S.E.A.T.M., 185
 Van Dijk J., 5
 Van Gestel C.A.M., 80
 Van Hal J.R., 229
 Van Rensburg L., 205
 Van Vliet P.C.J., 109, 185
 Vandenkoornhuysen P., 223
 Vázquez M.M., 76
 Vecchiato C., 223
 Velando A., 299, 300, 313
 Velasquez E., 231, 276
 Ventiöð J., 52
 Verhaagh M., 22, 57, 77, 98, 264
 Verhoef H.A., 5, 229
 Veselý M., 294
 Vestberg M., 163, 164
 Viallatoux A., 239
 Viktorov A.G., 314
 Villányi I., 234
 Villenave C., 154, 237, 239
 Voigtländer K., 78
 Wada E., 162
 Wanner M., 14
 Watt A., 252
 Weibel D., 91
 Weigel H.-J., 221, 286
 Whalen J., 142
 Wickings K., 85
 Wigger S., 47
 Winchester N., 20
 Winsome T., 321
 Wolters V., 79, 84, 122
 Xylander W.E.R., 14
 Yamahatsu K., 289
 Yamashita N., 199, 289
 Young I., 170
 Yuhui Q., 296
 Yunfeng C., 189
 Yurkov, 147
 Zaitsev A.S., 79, 84, 172
 Zaller J.G., 90
 Zhang X., 170
 Zhenjun S., 315, 316, 317
 Zhiping C., 189, 190, 296
 Zorn M.I., 80
 Zou X., 321, 325