

# THE EFFECT OF SOIL TYPE AND SOIL MOISTURE ON EARTHWORM COMMUNITIES

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**ABSTRACT.** Twenty four study areas of three most widespread soil types (pebble rendzinas, typical brown soils and pseudopodzolic soils) all over Estonia were selected. In each group of soil type, eight fields were selected for studies in 2003–2004. The mean abundance of earthworm communities was the highest in pseudopodzolic soils ( $107.11 \pm 22.4$  individuals per  $m^2$ ) and lower in pebble rendzinas ( $47.94 \pm 11.25$  individuals per  $m^2$ ) and typical brown soils ( $72.97 \pm 15.13$  individuals per  $m^2$ ). The number of earthworm species in a community was 1–6. In all fields 7 species of earthworms were found, also a few individuals of 3 species. Soil moisture influences the abundance of earthworm communities more than soil type whereas ecological and specific structures are less influenced by soil moisture. Pebble rendzinas are suitable habitats for earthworms but periodical drying out decreases the abundance of earthworms. In pseudopodzolic soils the abundance is higher if there are optimal moisture conditions, due to increasing abundance of ecologically tolerant endogeic species. In typical brown soils the diversity and number of juvenile individuals is high which indicates suitable conditions for habitat in this type of soil.

**Keywords:** earthworms, abundance, biological diversity, soil microbial community, soil type, soil moisture.

## Introduction

Earthworms' role in promoting soil fertility makes them probably the most important, in terms of their relevance to productivity, of all animal groups that share with mankind the earth's land surface (Lee, 1985). Soil meso- and macrofauna enhance the mineralization of organic matter through litter fragmentation and inoculation of microorganisms. According to Edwards and Bohlen (1996) there are about 220 species of lumbricids, of which 19 are common in Europe. Thirteen species have been identified in Estonia (Timm, 1999), including species from the genera *Lumbricus*, *Allolobophora*, *Aporrectodea*, *Dendrobaena*, *Dendrodrilus*, *Eisenia*, *Octolasion* and *Eiseniella*. Earthworm communities are typically stratified vertically into ecologically distinct groups of species that usually do not relate closely to taxonomic categories. Although the three groups are distinguished primarily on the basis of the vertical stratification of their preferred habitats in the soil, species in each of the groups share a variety of morphological, behavioural and demographic characters (Bouché, 1977; Lee, 1991).

Edwards and Bohlen (1996) say that the parameters of earthworms' community can indicate a number of soil characteristics (soil texture, content of organic matter, porosity, intensity of water movement in soil, acidity, moisture, temperature, concentration of some ions, also some characteristics of vegetation). Species number and ecological categories (e.g. epigeic, endogeic and anecic) are favoured by Paoletti (1999) as key indication parameters in agroecosystems. Atlavinyte claims that (1990) changes in the number of earthworms and other soil organisms, their species composition function as indicators of soil fertility and its exhaustion and pollution.

The aim of the research was to study the abundance and diversity of earthworm communities in three types of arable soils and the factors affecting the communities.

## Material and methods

Twenty four study areas of three most widespread soil types (pebble rendzinas, typical brown soils and pseudopodzolic soils) all over Estonia were selected. In each group of soil type, eight fields were selected for studies in 2003–2004. The cover crops (2003: 19 cereal fields, 3 clover field, 1 oilseed field, 1 perennial grass field; 2004: 20 cereal fields, 2 oilseed fields, 1 perennial grass field) and three-year history of agricultural management practice (amount of mineral and organic fertilizers and pesticides used) were recorded. To compare the results, the database of earthworms from 1996–2001 (56 study fields with several soil types) and 42 cereal fields from 2004 was used.

In all study areas five soil blocks of  $50 \times 50 \times 40$  cm were studied by hand sorting method introduced by Meyer (1996), the living earthworms were washed, kept 48 hours in refrigerator and counted. The species were identified based on Graff (1953), Timm (1999) and Bährmann (1995) classification. The mean number of individuals in  $1 m^2$  of soil surface and standard error (SE) were calculated. In all composite soil samples moisture content ( $105^\circ C$ ), pH, organic matter content (in muffle oven at  $360^\circ C$ ), nitrogen concentration (by the Kjeldahl method), soluble phosphorus concentration (by lactate method) and the concentration of potassium (by flame photometer) were determined.

Total activity of microbial community was measured using fluorescein diacetate method which estimates the activity of dehydrogenase enzymes in a composite sample (Schnürer, Roswall, 1982).

Data analysis was performed using nonparametric statistical methods (dispersion analysis of Kruskal-Wallis, Mann-Whitney U-test, Spearman's correlation analysis). The Shannon index of diversity was calculated.

## Results

The mean values of soil characteristics are given in Table 1. Statistically significant differences between mean values of soil types were not found.

**Table 1.** Characteristics of soil of studied fields (mean value  $\pm$ SE)

Number	Pebble rendzinas n=8	Typical brown boils n=8	Pseudopodzolic soils n=8
Soil moisture, %	15.95 $\pm$ 0.29	16.34 $\pm$ 0.05	18.58 $\pm$ 0.59
pH	7.07 $\pm$ 0.12	6.92 $\pm$ 0.07	6.23 $\pm$ 0.3
Organic matter content, %	4.15 $\pm$ 0.65	3.45 $\pm$ 0.26	4.16 $\pm$ 0.99
Total N, %	0.207 $\pm$ 0.037	0.158 $\pm$ 0.012	0.201 $\pm$ 0.055
Soluble P, mg per 100 g dry soil	16.91 $\pm$ 3.18	11.19 $\pm$ 1.7	14.34 $\pm$ 2.78
K <sup>+</sup> , mg per 100 g dry soil	18.24 $\pm$ 3.3	21.32 $\pm$ 2.1	17.24 $\pm$ 2.86

**Table 2.** Characteristics of earthworm communities (mean value  $\pm$ SE) in the fields of different soil type. Mean values statistically different from others are marked with an asterisk (\*)

Number	Pebble rendzinas	Typical brown soils	Pseudopodzolic soils
Abundance, individuals per m <sup>2</sup>	47.94 $\pm$ 11.25	72.97 $\pm$ 15.13	107.11 $\pm$ 22.4*
Number of species	3.2 $\pm$ 0.5	3.5 $\pm$ 0.26	3.1 $\pm$ 0.5
Epigeic individuals, %	3.7 $\pm$ 2.1	7.0 $\pm$ 3.2	2.2 $\pm$ 1.0
Endogeic individuals, %	85.2 $\pm$ 4.3	81.5 $\pm$ 6.1	89.8 $\pm$ 2.3
Anecic individuals, %	11.1 $\pm$ 2.7	11.5 $\pm$ 4.5	8.0 $\pm$ 2.0
Biomass, g per m <sup>2</sup>	33.39 $\pm$ 6.44	29.32 $\pm$ 6.91	45.05 $\pm$ 8.51
Biomass of individual, g	0.79 $\pm$ 0.12	0.42 $\pm$ 0.05*	0.51 $\pm$ 0.07
Shannon's biodiversity index	0.841 $\pm$ 0.187	0.969 $\pm$ 0.135	0.831 $\pm$ 0.126
Hydrolytical activity of microbial community, OD/g	0.578 $\pm$ 0.025	0.582 $\pm$ 0.032	0.761 $\pm$ 0.073*

**Table 3.** Presence of earthworm species in the fields in 2003 and 2004 (number of fields where the individuals of the species were found)

Earthworm species	Pebble rendzinas n=8	Typical brown soils n=8	Pseudopodsolic soils n=8	Total n=24
<i>Aporrectodea caliginosa</i>	7	8	8	23
<i>Aporrectodea rosea</i>	7	8	8	23
<i>Allolobophora chlorotica</i>	0	1	3	4
<i>Octolasion cyaneum</i>	1	0	0	1
<i>Aporrectodea longa</i>	4	2	3	9
<i>Lumbricus terrestris</i>	4	4	4	16
<i>Lumbricus rubellus</i>	2	8	5	15

Statistically significant differences between mean values of soil types were: the number of earthworms (P=0.0141) and hydrolytical activity (P=0.0360) of microbial community (P=0.0364) in pseudopodzolic soils, the biomass of individual in typical brown soils.

In addition, a few of individuals of species *Lumbricus castaneus*, *Dendrodriulus rubidus*, *Eisenia foetida* were found in field soils in 1996–2001 and in 2004. In the soil of one field of pebble rendzina soil type (in the west of island Saaremaa, extremely thin and stony soil) no individuals of earthworms were found. In the soil of all other 23 fields the endogeic species *Aporrectodea caliginosa* ja *Aporrectodea rosea* were present. Other species were absent in some fields, endogeic *Octolasion cyaneum* was present only in one field.

There were no differences between mean values of characteristics of earthworm communities in the fields with different cover crop (cereals, oilseed and clover).

## Discussion

Arable land forms approximately a quarter of Estonian territory including pebble rendzinas (9.0% of Estonian arable land), typical brown soils (9.7% of arable land) and pseudopodzolic soils (15.1% of arable land) (Kõlli, Lemetti, 1999; Kõlli, Ellermäe, 2001). The three soil types differ in biological activity. There are optimal conditions (aeration, moisture and acidity) for soil microbial and invertebrates' communities in the upper layer of pebble rendzinas, albeit drought may harm soil communities in some years. In typical brown soils water regime is more stable during vegetation period and the activity of soil biota is high. Pseudopodzolic soils are characterized by low content of humus and relatively high acidity of soil because their biological activity is low. The abundance of earthworms may increase due to some agricultural activities (liming, organic fertilizing) (Kõlli, Lemetti, 1999).

According to Paoletti (1999) and Curry *et al.* (2002), earthworm populations in cultivated land are generally lower than those found in undisturbed habitats. Agricultural activities such as plowing, several tillage operations, fertilizing and application of chemical pesticides have dramatical effect on invertebrate animals. Any management practices applied to soils are likely to have some (positive or negative) effects on earthworm abundance and diversity, these effects are primarily the result of changes in soil temperature, soil moisture and organic matter quantity or quality (Hendrix, Edwards, 2004). Tillage, single crop, toxicants, soil acidification and residue removal are the factors decreasing earthworm abundance and diversity, whereas no tillage management, rotation of crop, liming and organic amendments are the increasing factors of earthworm abundance and diversity. In general, the greater the intensity and frequency of disturbance, the lower the population density or biomass of earthworms (Mckay, Kladvko, 1985). Earthworms are attributed directly to injury caused by cultivation or indirectly to habitat disruption and reduction in food supply as well as a result of high predation during and after tillage operations. Lavelle *et al.* (1997) say that the effects of intensification of land use on earthworm communities are loss of diversity and loss of litter feeders, the effect of pollution on earthworms are changes in specific composition.

Earthworms may contribute to decomposition of organic matter and N mineralization directly, by affecting the growth rates of other populations of soil organisms through grazing (e.g. negatively through reduction of the prey number or positively by reducing growth limiting factors for the soil organisms), by influencing soil moisture and aeration through soil structure, by fragmenting and redistribution of plant material and excreting nutrient rich faeces; the indirect contribution are difficult to separate (Marinissen, de Ruiter, 1993). There is evidence that measures of the size and activity of the soil communities, e.g. earthworm numbers, microbial biomass, soil respiration and soil enzymes activity, have considerable potential as early indicators of soil degradation or improvement (Haynes, Tregurtha, 1999). The use of soil macrofauna and earthworms in particular as bioindicators relies on their prominent place in the community of soil organisms and their function in promoting processes that are considered to be linked to soil health (Doube, Schmidt, 1997). Lavelle and Spain (2001) admit that the regional abundance of earthworms and the relative importance of the different ecological categories are determined by large scale climatic factors (mainly temperature and rainfall) as well as by their phylogenetic and biogeographical histories together with regional parameters such as vegetation type and soil characteristics.

There were five earthworm species found in all three types of soil. The dominant endogeic species *Aporrectodea caliginosa* formed at least 75% of all individuals of communities, the endogeic species *Aporrectodea rosea*, epigeis *Lumbricus rubellus* as well as anecic *Aporrectodea longa* and *Lumbricus terrestris* were present. Pebble rendzinas was different from other soil types considering the composition of earthworms – the individuals of species *Allolobophora chlorotica* were absent here. This species is sensitive to soil conditions and temporarily drying out pebble rendzinas are not suitable for this species. In the soil of one field we found individuals of species *Octolasion cyaneum* (Table 2). This species is not common in Estonia but in some regions the abundance could be quite high, in this case it can be competitor for the most common species *Aporrectodea caliginosa* because of similar demand of ecological condition and tolerance to agricultural activities. The specific composition of a community is a good indicator of agricultural practice intensity in the field. The occurrence of species only like *Aporrectodea caliginosa*, *Aporrectodea rosea*, *Lumbricus rubellus* tolerant to conditions and disturbance is the result of intensive tillage and agricultural practice or the influence of strong limiting ecological factor (mostly too low moisture). A community including more sensitive species indicates more suitable ecological or agricultural factors for habitat (Ivask, Kuu, 2005).

Comparing the three soil types the highest abundance of earthworms as well as hydrolytical activity of microbial community (Table 2) was found in pseudopodzolic soils. Kõlli and Lemetti (1999) claim that this type of soil has low biological activity. It was assumed that the abundance of earthworms would be the lowest in pseudopodzolic soils because of soil characteristics. The unequal distribution of precipitation in 2003–2004 (Keskkonnaülevaade, 2005) was the reason for highest abundance of earthworms in the South and East of Estonia, in the region where pseudopodzolic soils mostly are distributed. The abundance increased because of the increase in the number of ecologically tolerant species *Aporrectodea caliginosa* and endogeic individuals of

other species. Ecological structure of earthworm communities in pseudopodzolic soils (the biggest portion of endogeic individuals and the smallest portion of epigeic and anecic species, in comparison with communities of other soil types, Table 2) indicates that pseudopodsolic soils are not optimal habitat for earthworms. Biologically active pebble rendzinas are distributed in the West and North of Estonia where the amount of precipitation was low and the soils dried out periodically. Typical brown soils are biologically more active according to some authors (Kõlli, Lemetti, 1999), the soil moisture conditions in 2003–2004 here were optimal and did not limit the abundance of earthworms (Table 3). In typical brown soils the body mass of individuals was the smallest (statistically significant difference,  $P < 0.005$ ), so it can be concluded that the community included the highest number of juveniles. The biodiversity index was the highest in this type of soil; the difference was statistically not significant.

### Summary

The mean abundance of earthworm communities was the highest in pseudopodzolic soils and lower in pebble rendzinas and typical brown soils. The number of earthworm species in the community was 1–6. In all fields 7 species of earthworms were found also a few individuals of 3 species. Soil moisture influences the abundance of earthworm communities more than soil type; the ecological and specific structures are less influenced by soil moisture.

Pebble rendzinas are suitable habitats for earthworms but periodical drying out decreases the abundance of earthworms. In pseudopodzolic soils the abundance is higher if there are optimal moisture conditions, due to increasing abundance of ecologically tolerant endogeic species. In typical brown soils the diversity of earthworms and number of juvenile individuals are high which indicates suitable conditions for habitat in this type of soil.

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