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Original article

# Earthworm communities in relation to tree diversity in a deciduous forest

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**Abstract**

The understanding of belowground biodiversity is still rather incomplete and interactions between above- and belowground systems have rarely been looked at when explaining belowground biodiversity patterns. The present study presents results of the influence of tree species diversity on the earthworm community in a central European deciduous mixed forest. Within the Hainich National Park three replicate sites were chosen within three levels of tree diversity ranging from one species (beech, DL1) to three species (beech, lime, ash, DL2) to five species stands (beech, lime, ash, hornbeam, maple, DL3). Earthworms were extracted by heat from soil and litter samples at four sampling dates at each site. In addition, in spring four samples per site were sorted by hand and identified to species level. Generally, earthworm densities were positively correlated with tree diversity in May and November but negatively in February. Sites with low tree species diversity had earthworm populations which were more stable due to a more permanent and deeper litter layer. Increasing proportions of high quality litter in DL2 und DL3 were correlated with higher densities of both epigeic and endogeic earthworm species, while litter in DL1 sites was mainly inhabited by epigeic species. Generally, there was a positive correlation between earthworm and tree species diversity indicating the importance of diverse food qualities for the decomposer fauna at the local scale especially in springtime.


*Keywords:* Lumbricidae; Earthworm diversity; Tree diversity; Mixed forest; Beech; Lime; Ash

## 1. Introduction

Central European forestry management is changing and more and more monospecific stands are transformed into mixed stands. This influences stand microclimate, soil characteristics and soil biota [3,9,26,31]. However, little is known about the influence of different levels of tree diversity on belowground processes and soil animal communities [7,28]. Earthworms and trees are both considered ecosystem engineers [12] modifying the habitat they live in. While different ecological groups of earthworms (epigeic, endogeic, anecic) play different but equally important roles in forest nutrient cycling [18], tree litter quality influences earthworm food choice (e.g. refs. [36,10]), reproduction [11] and biomass (e.g. refs. [20,17]). Thus, the effect of plant species on ecosystems processes results from 'their effect on those soil organisms that drive the processes' [34]. However, the reverse also has been shown that soil organisms such as litter feeding macrofauna can alter effects induced by litter species diversity [8]. The understanding

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of belowground biodiversity is rather incomplete and interactions between above- and belowground systems need to be looked at when explaining belowground biodiversity patterns [34,30].

The Hainich National Park in Central Germany is a mosaic of beech-dominated deciduous forests where diversity hotspots with up to 10 tree species per 250 $m^2$ can be found next to near monospecific stands. This paper presents results on the earthworm community at three levels of tree diversity (low, medium, high) in this forest. The main questions of this paper are if earthworm density and diversity are correlated with tree diversity and which factors (among them litter depths and diversity, pH, moisture, and diversity of the herb layer) influence the earthworm community in mixed forests of the same soil types and similar humus forms.

## 2. Materials and methods

### 2.1. Site description

The study sites are located in the Hainich National Park in central Germany (province of Thuringia). With a size of 7600 ha the Hainich is the greatest cohesive deciduous forest area in Germany. It is a limestone mountain range covered by a homogeneous loess layer [14] reaching in parts a maximum elevation of 494 m a.s.l. (annual temperature of 7.5 °C, annual rainfall of 700 mm). The soil type is a luvisol with pH ranging from 3.8 to 6.1 in soil (Table 1). Humus forms range from L-mull to F-mull [24]. The forest is dominated by beech (*Fagus sylvatica*) but locally a mosaic of up to 10 tree species occurs with varying composition within 500 m ranges. According to the dominant tree species, three replicate study sites of 50 × 50 $m^2$ were chosen for each of three levels of tree diversity. Diversity level (DL) 1 was dominated by beech, DL2 by beech, lime (*Tilia cordata*) and ash (*Fraxinus excelsior*) and DL3 by beech, lime, ash, hornbeam (*Carpinus betulus*) and maple (*Acer* spp.[1]). Clusters of sites are indicated in Table 1 while a detailed map is given in ref. [14]. Actual tree diversity within diversity levels differed slightly, thus in the graphics displayed here, sites are arranged according to the Shannon–Wiener diversity index of tree species crown area.

[1] Several maple species of were present: *A. pseudoplatanus, A. platanoides*, rarely *A. campestre.*

### 2.2. Sampling

In May, August, November (all 2005) and February 2006 soil cores (0.035 $m^2$, organic layer and 5 cm of upper mineral soil) were taken from six plots (6 × 5 m) of each site. Litter depth was measured and earthworms were extracted by heat and counted. In addition, soil and litter samples were taken from each plot to measure gravimetric soil moisture content and $pH_{CaCl_2}$. Diversity of herb cover and tree crown area was measured within each site and expressed as Shannon-diversity index per site ([14], M. Brauns unpublished). In spring (April 2006) when all earthworm species are active and representation of community structure is best, four samples (0.11 $m^2$, 20 cm depth) were taken along the sides of each site (min. 20 m apart), hand-sorted, anecic earthworms were extracted from the hole using a 0.33% mustard solution [6], and specimens were identified to species level.

### 2.3. Statistical analysis

Raw density data from heat extraction (individuals per sample, four sampling dates) were analysed for diversity level effects for each date (one-way analysis of variance, ANOVA, with the factor ‘diversity level DL’) and for diversity level changes throughout the year (repeated ANOVA with MANOVA statistic using Roy’s greatest root [RGR] for the factors DL and time, SAS 8.2, SAS Institute [25]). Each date was analysed separately first to test for site (=within-DL) effects (site used as error term in a nested ANOVA). A significant site effect requires per site averaging of samples before analysing for diversity level effects. There was no significant site effect for heat extraction data, but for hand-sorting data mean values per site had to be used for the ANOVA of diversity level effects. Tukey’s test was performed to test for differences between means. Data were log-transformed to achieve homogeneity of variances and normality.

Redundancy analysis was performed using raw mean lumbricid species density per site, soil/litter pH and litter moisture, herb diversity (Shannon index) and litter depth as environmental data and dominance of beech, lime and ash as supplementary (passive) variables.

Shannon–Wiener diversity index was calculated for lumbricid species per plot and mean diversity was correlated with tree diversity using Spearman’s Rho correlation coefficient.