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Original article

Earthworm communities in temperate beech wood forest soils affected by liming

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ABSTRACT

To monitor the effects of liming on forest ecosystems, experimental plots were installed in forests in mid-western Germany. In addition to soil chemical indices, earthworm communities were investigated on these plots about 15 years after first lime applications took place. As a ''natural reference'', communities were compared to earthworm records that derived from a beech forest on limestone. In the non-acidified plots that had never been limed only epigeic earthworms were detected in small numbers and low species richness. Forest liming caused higher pH and a higher base saturation in the mineral topsoils. To a large extent, epigeic earthworm species seemed to benefit from this and had increased in number and biomass at all three different locations selected for the investigations. The epigeic dominated communities were completed by anecic *Lumbricus terrestris* that was rarely found in some of the samples from one location and a number of endogeic species that showed a very patchy distribution in limed plots. In contrast to this, the soil of the beech forest on limestone showed a different community composition. It was dominated by endogeic species in abundance and by anecic species in biomass. On limestone the total biomass of earthworms clearly exceeded the biomass values from all other plots. In conclusion, a long-term support of forest earthworm fauna due to liming was detected. This support was mainly effective for epigeic species, but in some cases for endogeic and anecic species, too.

1. Introduction

High acid loads have acidified forest soils in wide areas of Germany, putting numerous ecosystem functions at risk [24,31]. The buffering capacity of mineral soils has decreased and element cycling has suffered. In consequence, species composition of understory and groundcover vegetation has changed [9]. Due to low Ca/Al ratios in soil solution, toxic effects on fine root growth have occurred and groundwater has become highly contaminated with aluminium [30,22]. Moreover, earthworms, the most effective group of macrofauna engineers on soil structure and soil fertility [8,14,16], have largely become extinct in forest soils [33]. Especially endogeic (soil living) species like *Aporrectodea caliginosa* or *Aporrectodea rosea* are

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not tolerant to pH (H_2O) values lower than 4.5, while epigeic (surface) species are often more tolerant to lower pH values. *Lumbricus terrestris*, an anecic (deep burrowing) species, takes an intermediate position [7,8]. For this reason, the species expected to be the last to survive in acidified soils are epigeic, and as a consequence bioturbation and humus formation in upper mineral layers is reduced. Together with general reductions in biological turnover of soil organic matter due to lower pH, this leads to increasing humus accumulation on the surface.

In order to compensate soil acidification, about 48% of the forests have been limed since the early 1980s in the German federal state of North Rhine-Westphalia (NRW). Along with the applications, research plots in selected forest areas were installed to monitor the effects of forest liming [19]. This study addresses the question of whether long-term effects of liming on the earthworm communities are detectable about 15 years after the first applications. Three locations were selected covering different landscapes and soil types in NRW. In addition, the earthworm community in a beech forest on calcareous bedrock was investigated as a non-acidified and non-limed reference.

2. Material and methods

2.1. Locations

Four forest floors of beech stands in North Rhine-Westphalia (NRW) were investigated (Table 1). Three locations (Obereimer, Monschau, Kleve) consisted of an untreated (non-limed) control plot (NIL) and plots where lime or lignite ash was applied. First application took place in 1983. Except for the NIL plot, areas of about 1 ha received 6 t lime ha^{-1}. A second application of lime was carried out in 1990. At "Kleve" a subplot of the limed plot received an additional 3 t lime ha^{-1}. At Monschau a subplot received another 6 t lime ha^{-1}. At Obereimer an additional 6 t lime ha^{-1} was applied to the whole limed plot, which meant that there were no subplots of different lime amounts as in Monschau and Kleve. At Obereimer a single treatment of ash application (6 t ha^{-1}) covering another 1 ha of the forest floor was established in 1994. The ash was derived from power plants burning lignite. The three locations with lime applications were investigated in 3 subsequent years (1998, Obereimer; 1999, Kleve; and 2000, Monschau).

The fourth location representing a comparable beech stand on limestone was investigated in 2002. This location (Bad Driburg) was used as a reference that was never exposed to acidification due to a "natural" buffering from parent rock.

2.2. Analysis

At each location, lime treatments were carried out on an area of 1 ha (100 m × 100 m). A virtual grid of 10 m by 10 m square cells was levelled for each of the 1 ha investigation areas. Hence, 100 grid cells represented the treatments NIL at all locations, lime and ash in Obereimer. Due to the second liming in Monschau and Kleve on half of the experimental area, only 50 grid cells corresponding to an area of 50 m × 100 m represented the treatments lime 1 and lime 2. Using information on pH values from earlier studies, grid cells were selected for earthworm

Table 1 – Summary of some important characteristics of the locations and treatments in this study

Location	Obereimer	Monschau	Kleve	Bad Driburg
Geographic position	51°25′03.36″N; 8°16′25.06″E	50°42′19.82″N; 6°20′05.35″E	51°44′55.77″N; 5°59′13.32″E	51°39′58.92″N; 9°00′38.03″E
Elevation above sea level (m)	490	440	60	300
Precipitation, long-term annual average (mm)	1000	1100	750	850
Temperature long-term annual average (°C)	7	6.5	9.5	8
Parent rock	Carboniferous siltstone	Cambrian sand-siltstone	Quaternary rhine terraces covered by Aeolian sands and loess	Limestone
Soil	Gleyic cambisol, sandy silt	Gleyic cambisol, sandy silt	Spodic cambisol, silty sand	Eutric cambisol silty clay
Humus layer classification	Ranging from moder to mor	Ranging from mull to moder	Ranging from moder to mor	Typical mull (litter layer only)
Growing stock	135–150 years old *Fagus sylvatica*, fully stocked	130–150 years old *Fagus sylvatica*, fully stocked	130–160 years old *Fagus sylvatica*, fully stocked	120–140 years old *Fagus sylvatica*, fully stocked + few *Fraxinus excelsior*
Treatments	NIL: no lime; lime: 2 × 6 t (1983, 1990); ash: 1 × 6 t (1994)	NIL: no lime; lime1: 6 t (1983); lime 2: additional 6 t (1990)	NIL: no lime; lime1: 6 t (1983); lime 2: additional 3 t (1990)	No specific treatments
Year of investigation	1998	2000	1999	2002