Critical values of soil acidification for annelid species and the decomposer community

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Abstract

The composition of the annelid coenosis (earthworms, enchytraeids and other microannelids) of 54 soil monitoring sites in northwest Germany was investigated. The monitoring sites cover all important soils, substrates and management types. pH-values ($CaCl_2$) in the topsoil range from 2.9 to 7.4. Along the gradient of soil reaction, the distribution curves of different annelid species are presented. By overlaying the curves, typical areas of similar respectively diverse species composition emerge, which correspond to different decomposer community types. This form of presentation visualizes at which degree of soil acidification the soil faunal community switches from one domain to another. It is considered under which conditions liming may shift the community into the domain where soil dwelling earthworms will initiate an improvement of the humus form.

Keywords: Enchytraeidae; Lumbricidae; acidification; decomposer community; humus form

1 Introduction

Soil reaction is an important environmental factor for many soil organisms. Especially soil animals living in direct contact with the soil solution are strongly influenced by soil acidity. This applies also to earthworms and microannelids which belong to the major faunal decomposers.

The dependence of species composition on soil acidity has been shown repeatedly during the last decades (Abrahamsen 1972, Healy 1980, Graefe & Schmelz 1999).The aim of this contribution is to present a pattern how the species distribution of the annelid coenosis changes with soil reaction. These changes can be understood as continuous process accompanying acidification. On the other hand, we find threshold values for single species as well as for the decomposer community. If these critical values mark decisive changes in soil conditions they should be related to changes in other structural elements of the soil system. Our understanding of this problem touches also the question of adequate protection and melioration measures to reverse the acidification process and its effects on soil organisms.

The observations presented are based on data from zoological investigations on soil monitoring sites in Schleswig-Holstein, Hamburg and North Rhine-Westphalia. Earthworms and small annelids (enchytraeids, tubificids and polychaetes) were examined representing the macro- and mesofauna respectively (Graefe & Beylich 2002).

2 Methods

A standardized set of methods was used for soil sampling and extraction (Graefe et al. 1998). Ten samples were taken at each site. Earthworm sampling was carried out by a combination of formalin extraction, handsorting and heat extraction. Enchytraeid samples were extracted by a wet- funnel method without heating (Dunger & Fiedler 1989).

3 Results and discussion

The soil reaction of the 54 examined soil monitoring sites is shown in Figure 1. pH-values ($CaCl_2$) in the topsoil are distributed more or

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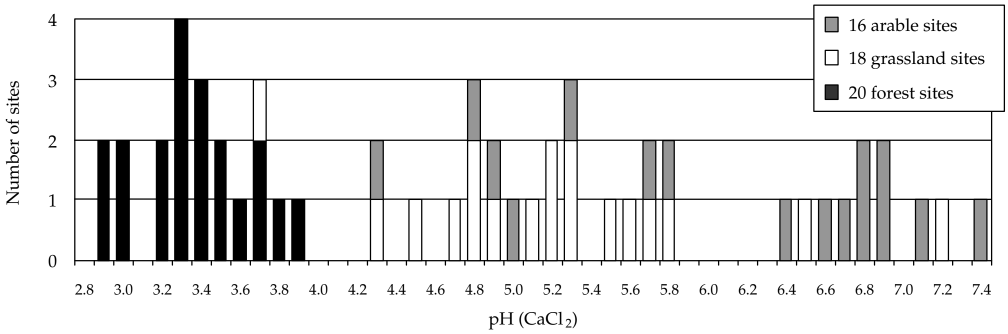

Figure 1: pH-values in the humus layer and the topsoil of 54 soil monitoring sites in northwest Germany.

less evenly over the whole range from 2.9 to 7.4. While the forest sites are strongly acid, arable sites predominate in the pH-range above 6.2. Fields on sandy soils are generally more acid than those on loam. Grassland sites hold an intermediate position.

The distribution of different species along the gradient of soil reaction is shown in Figure 2. Indicators of strong acidity such as *Marionina clavata* show highest densities around pH 3 and are absent above pH 4.0. On the other hand, soil dwelling earthworms like *Lumbricus terrestris* or *Aporrectodea caliginosa* are restricted mainly to pH-values higher than 4.2, although we find singular relict populations of these species at sites with lower pH-values in the topsoil. Their existence can be explained by a higher base saturation in the subsoil. Each species tolerates a certain range of soil pH and prefers a narrower zone within this range. Within the tolerated pH-range, many species occur in forest sites as well as in arable or grassland sites. Therefore, land use is not considered a primary factor for the occurrence of annelid species.

In a further step we overlay the distribution curves of different species and thereby turn from the species level to the level of the community. We find two domains with different species composition (Fig. 3). Along the pH-gradient the areas of *Lumbricus terrestris*, *Aporrectodea caliginosa*, *Allolobophora chlorotica* and many enchytraeid species like *Fridericia bulboides* or *Henlea perpusilla* are roughly identical. These species belong to the same type of decomposer community (Lumbricetalia) as does also *Aporrectodea longa*, which shows a more restricted amplitude. In contrast, *Cognettia sphagnetorum*, *Marionina clavata* and *Achaeta camerani* represent a different type of decomposer community (Cognettietalia). There are some species, such as *Enchytraeus norvegicus*, *Enchytronia parva* and the polychaete *Hrabeiella periglandulata*, that show an intermediate behaviour. They may occur in both decomposer community types and are characteristic for transition system states (Graefe 1993).

The picture as a whole does not change substantially when we add further species distribution curves. The turning point between the two community types lies at about pH 4.2 ($CaCl_2$), which corresponds with the transition from exchanger buffer range to aluminium buffer range sensu Ulrich (1981). The borderline between both buffer ranges can be considered as a toxicity threshold caused by toxic aluminium ions in the soil solution. This can also be shown in laboratory tests with enchytraeids (Graefe 1991). Aluminium toxicity is well known in mineral horizons poor in humus, but it is of no importance in the humus layer. For that reason, predominantly endogeic and anecic earthworm species are affected. Their bioturbative activity is decisive for the development of mull humus forms. The border between Lumbricetalia and Cognettietalia therefore corresponds with the border between mull and moder (Graefe 2001).

When aluminium toxicity occurs, liming has often been proposed as a measure to improve soil conditions. The limed sites investigated by us did not show an increase of pH above a value

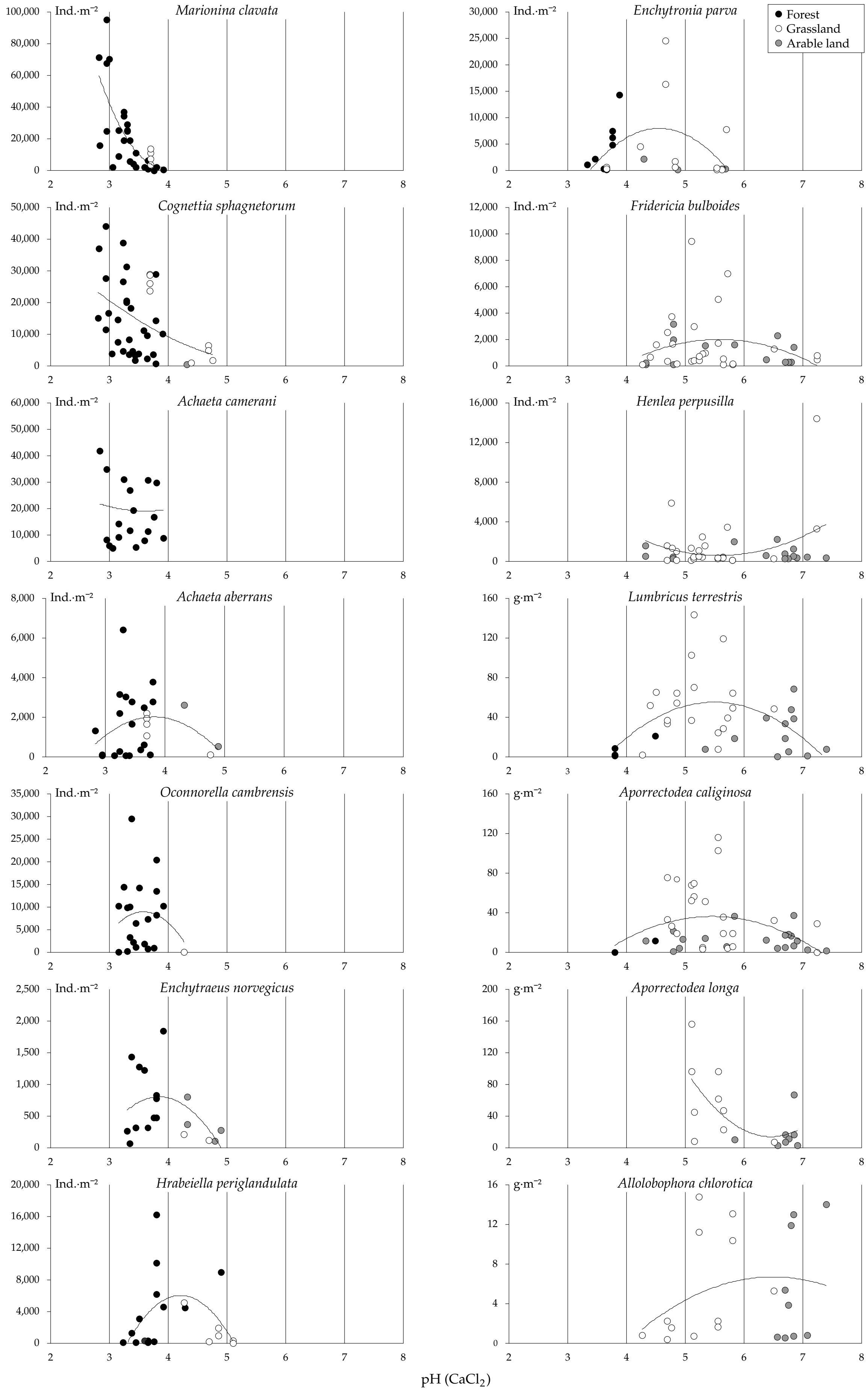

Figure 2: Distribution of different species along the gradient of soil reaction.

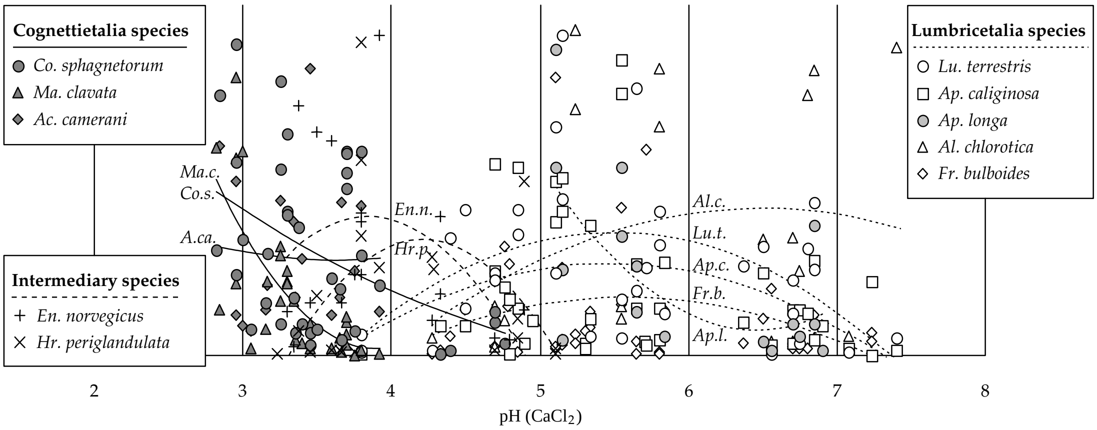

Figure 3: Distribution curves of 4 earthworm and 6 microannelid species along the gradient of soil reaction. No scaling for the y-axis is given as the scaling varies for the different species.

of 4.2 ($CaCl_2$) in the mineral soil so far (e.g. Fig. 5: Duisburg-Stadtwald). Under these conditions the species composition only changes in favour of a higher amount of indicators of moderate acidity (= intermediary species). Species belonging to the Lumbricetalia (= indicators of slightly acid to slightly alkaline conditions) are mostly not involved (Fig. 4). From a soil biological point of view, liming can be recommended if a remainder of soil dwelling earthworms (endogeic or anecic) is still present and in danger of extinction. In this case, which is often characterized by a steep pH-gradient from the soil surface downwards (e.g. Fig. 5 : Schwaney), a redevelopment of the pristine mull biocoenosis is possible.

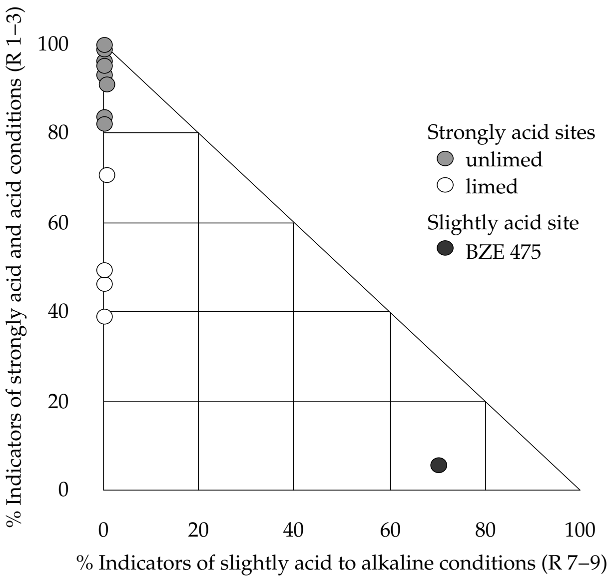

Figure 4: Diagram of microannelid reaction groups at forest sites. Liming with 3 t $CaCO_3 \cdot ha^{-1}$ has shifted the species composition to indicators of moderately acid conditions (R 4-6) but not to indicators of slightly acid to alkaline conditions (R 7-9).

It can be concluded that the change of species composition accompanying acidification is a process that shows a turning point at about pH 4.2. With the extinction of endogeic and anecic species and the development of mor or moder humus forms the soil system has passed a critical value beyond which effective melioration measures must be considered difficult, lengthy and costly.

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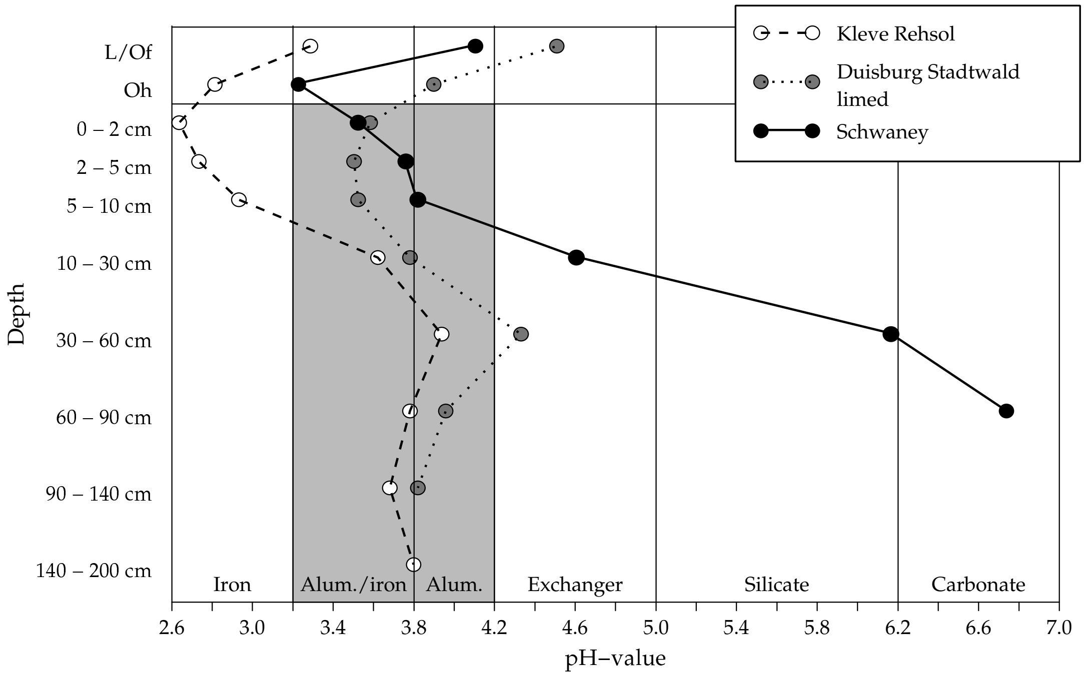

Figure 5: Depth profile of pH-values ($CaCl_2$) for three soil monitoring sites. Shaded area (= aluminium and aluminium/iron buffer range) represents potential stress for mineral soil dwelling annelids caused by aluminium toxicity.

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