Amelioration of acidified urban forest soils by liming – evaluation of effects on soil chemistry, soil biology and vegetation

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Introduction

Urban forests in the town of Essen (Ruhr district, Germany) are mainly beech and oak woodland on slightly podzolic loess soils. Soil investigations in 1985 revealed the strong acidification in soil profiles. The public authority of Essen decided to lime most of the forest area using 9-15 t/ha granulated dolomitic calcium carbonate between 1985 and 2003 in three steps (tab. 1). In order to control the impacts of the liming soil investigations were carried out in 2003 including chemical parameters, humus forms, decomposer communities (Lumbricidae and Enchytraeidae) and vegetation-surveys.

Tab. 1:
Total amount of lime given to the sites during the melioration (demand after SILVA, 1987)

Site	$CaMg(CO_3)_2$ (t/ha)	% of demand
209 A-L	15	60 %
216 A-L	10	41 %
837 A-L	9	28 %
837 D-L	13	105 %
837 E-L	11	104 %
837 B-L	9	63 %

Methods

The field investigations were based on the German forest soil monitoring program BZE (1994). The sampling covered the organic layers and the mineral soil (0-60 cm).

The chemical analysis was done in springtime of 2003 according to the protocols of the BZE-publication. Earthworms (Lumbricidae) were collected by hand from dig outs (500 cm², depth

10 cm) and by expulsion with mustard (DIN ISO 11268-3) from 0.25 m² areas. Enchytraeidae were extracted from soil samples by a wet-funnel method according to Graefe. Soil columns including the organic layers were divided into the depths 0-2.5 cm, 2.5-5 cm, 5-7.5 cm, 7.5-10 cm. The distribution and thickness of organic and mineral horizons in the soil columns was measured. Sampling was done in April 2003 with five sampling points at every stand in BZE arrangement.

The vegetation was described after Braun-Blanquet and the indicator values (reaction, nutrient) according to the Ellenberg systematic.

Results

Soil chemistry

The pH value (fig. 1) in the organic layers as well as the upper 10 cm increased considerably after liming. In spite of the long period of time the effects were only reduced to the organic layers and upper 10 cm of the mineral soil.

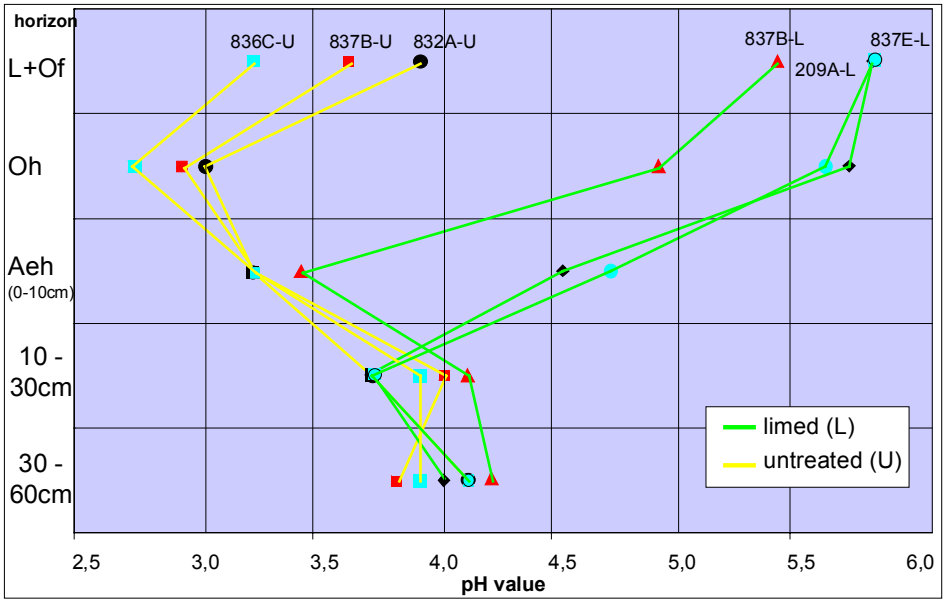

Fig. 1:
pH values of some investigation sites depending on the depth

Based upon the type of lime the offer of both Ca and Mg was enhanced (fig. 2) and the plant uptake (in particular Mg) increased simultaneously. These effects correspond with an improved vitality of the trees (Hübscher, 2003). The amount of some cations such as Ca, Mg, K, respectively, exceed the minimum contents in 0-60 cm depth (Ca: 200, Mg: 50, K: 200

kg/ha) according to the scientific proposals (BVB, 2000). The main problem of acidified forest soils, the lack of available magnesium, could be obviously solved.

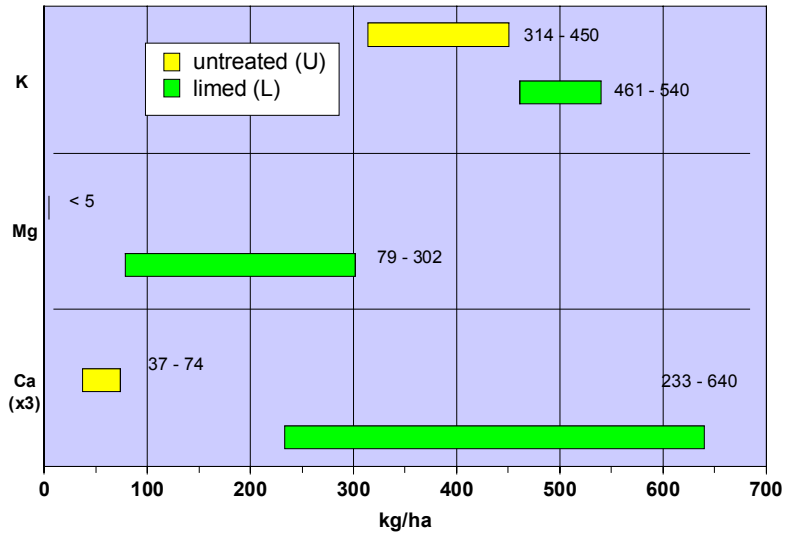

Fig. 2:
K, Mg and Ca content of the mineral soil (0-60 cm)

The Improved growth conditions are also indicated if you take the parameters CEC (effective), base saturation as well as Al+H saturation into account (tab. 2).

Tab. 2:
CEC, base saturation and Al+H-saturation
U = untreated, L = limed

	CEC (mmolc/100g)		base saturation (%)		Al+H saturation (%)
depth	**0-10 cm**	**10-30 cm**	**0-10 cm**	**10-30 cm**	**0-10 cm**
837B-U	11.7	5.3	8	3	88
837B-L	13.3	5.3	42	8	57
832A-U	9.8	5.0	9	4	85
837E-L	18.9	7.9	92	17	7
836C-U	13.4	6.1	3	2	94
209A-L	22.2	7.3	96	15	3
216A-U	10.4	5.0	14	7	81
216A-L	16.8	5.3	95	56	3
837A-U	9.0	5.0	10	3	86
837A-L	13.1	4.2	41	7	53

Repeated lime applications led to a decomposition of the organic layers. Thus, the monitoring involved the development of the organic matter content. As shown in fig. 3 the C content had lower values associated with the amount of lime applied. Resulting from the biodegradation the organic layers decreased in thickness while the organic matter content of the humic topsoil tended to higher values (bioturbation).

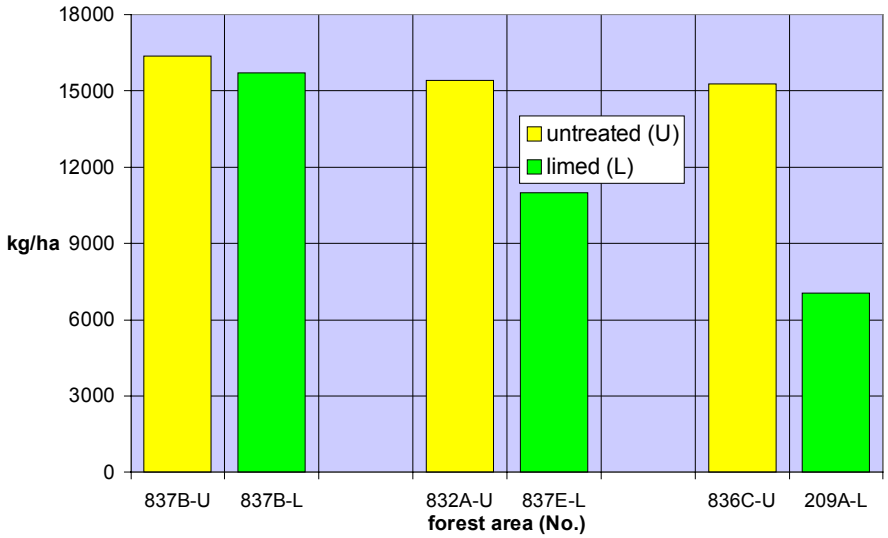

Fig. 3:
C content of the organic layers in pairs of limed vs. untreated forest areas

Soil biology

Liming was effective in creating soil conditions suitable for endogeic earthworms. Anecic species inhabiting deeper soil strata were missing at all sites (fig. 4). A reduction of Al+H - saturation below a threshold around 30 % is necessary for the development of strong populations of earthworms that live in the mineral soil. The lack of deep boring (anecic) species can be attributed to the still high Al+H - saturation in the soil below 10 cm depth (fig. 5).

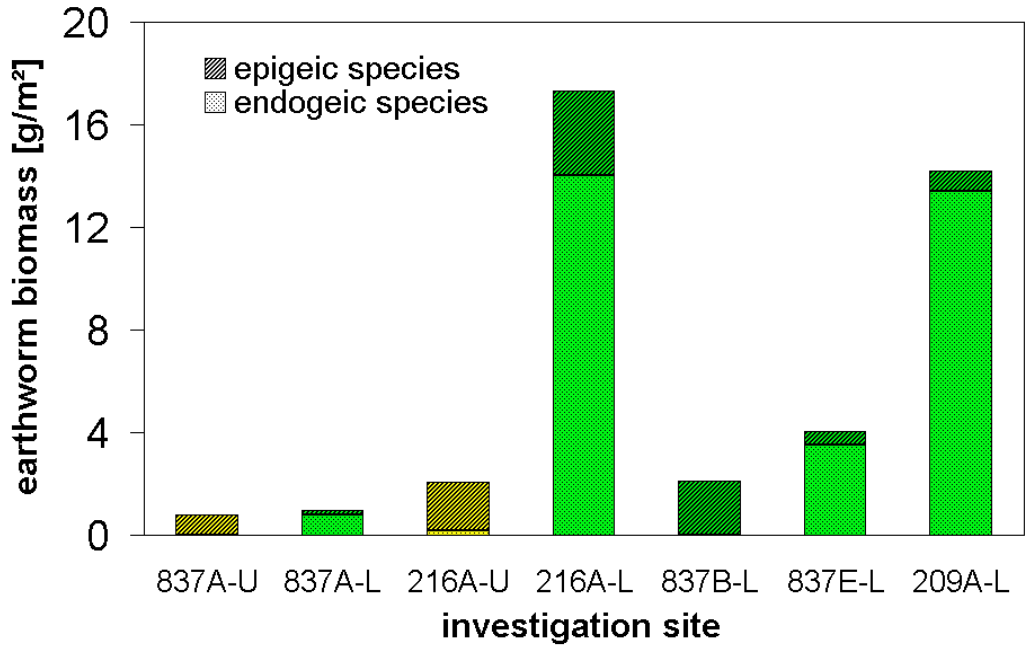

Fig. 4:

Earthworm biomass at the investigated sites divided into epigeic and endogeic life forms of species. There was no occurrence of anecic species at any site. -U = untreated, -L = limed site.

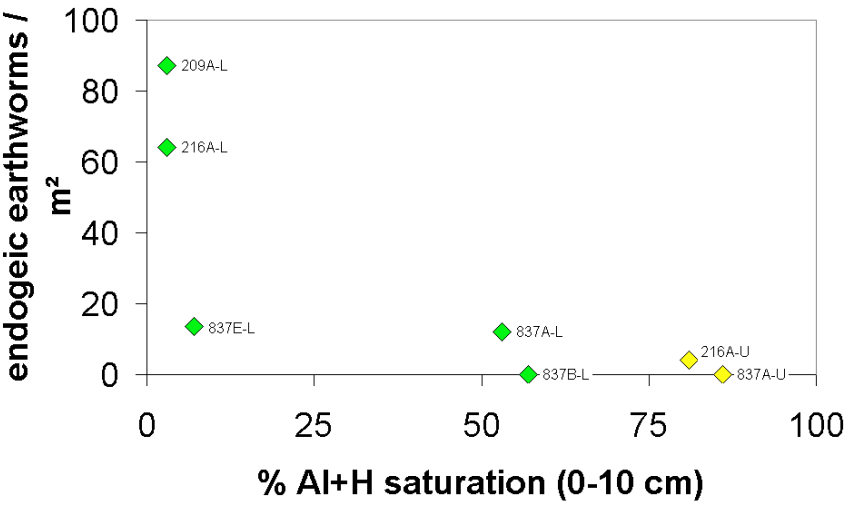

Fig. 5:

Abundance of endogeic earthworms in relation to the Al+H -saturation in the upper soil (0-10 cm) of five limed and two unlimed sites.

Liming influenced the abundance, species composition and vertical distribution of Enchytraeidae indicating a shift of biological activity from the organic layers into the mineral soil (fig. 6).

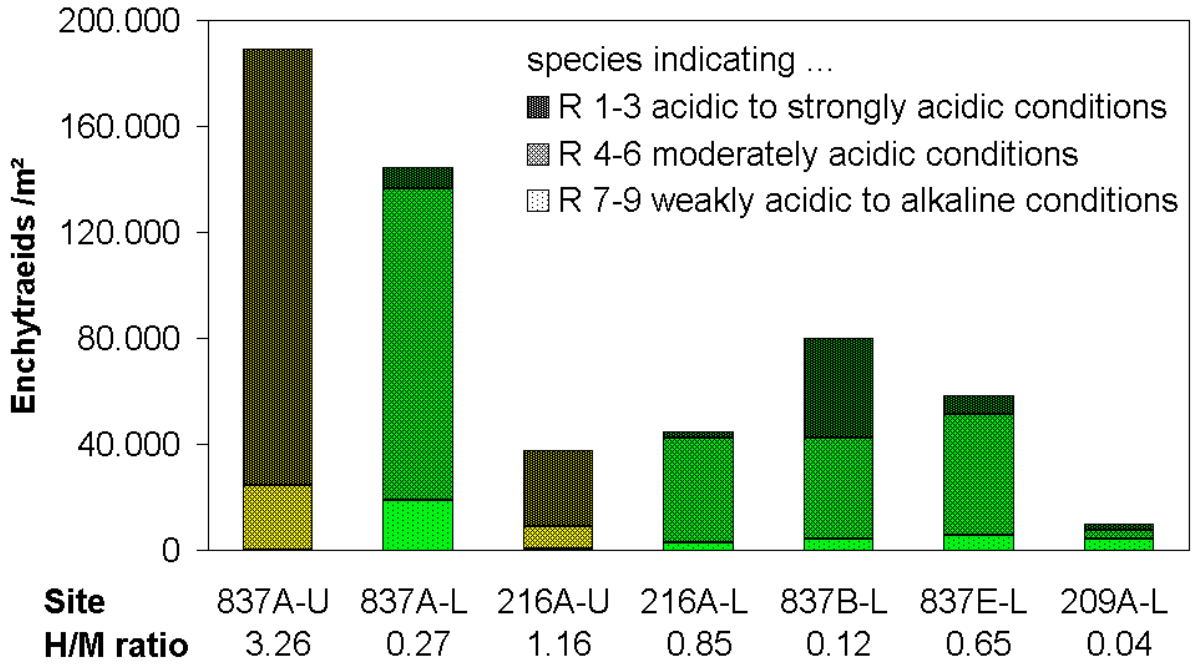

Fig. 6:

Enchytraeid abundance at the investigated sites divided into three categories of soil reaction indicator values (Graefe & Schmelz, 1999). O/M ratio is defined as [mean enchytraeid density in organic layer] / [mean enchytraeid density in mineral soil]

The following photographs inform about the visible changes in relation to the humus forms:

The photograph shows a typical moder humus profile of unlimed soil (soil core for enchytraeid extraction from site 837A-U). Markings on the drawer indicate 2.5 cm spaces. The organic horizons are L (1.5 cm), Of (1.5 cm) and Oh (2.5 cm).

This picture demonstrates earthworm (*Dendrobaena attemsi*) and enchytraeid (*Mesenchytraeus* sp.) in the organic layer of a limed forest soil (site 837A-L). High amounts of fecal aggregates between the plant litter show the increased activity of these epigeic species initiating a shift from moder to mull humus forms.

Liming in the forest stand 209A resulted in a mull like humus form although there are no anecic earthworms. Fallen leaves are covered with feces instead of pulling them into the soil. Burrows of moles (*Talpa europaea*) also indicate a high abundance of soil makrofauna.

Liming affected also the vegetation cover. The average reaction and nutrient indicator-values are clearly elevated at the treated sites (tab. 3), and the species composition changed into a nitrophilic vegetation not typical for beech forest flora on loess material.

Tab. 3:

Average and range of reaction and nutrient indicator-values of the vegetation at limed and untreated forest sites

	reaction value	**nutrient value**
limed	**5.7** [4.6 .. 6.6]	**6.3** [5.2 .. 7.8]
untreated	**3.8** [3.1 .. 4.0]	**4.4** [3.1 .. 5.8]

Conclusions

- There has been a substantial structural change of the soil system in the limed areas.
- Nevertheless the limed soils are different from natural base rich forest soils because there is continuing Al-toxicity in the subsoil.
- Therefore, liming has led to new man made soils which would never develop during natural pedogenesis

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