GENERAL INFORMATION

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MATERIAL & METHODS

study area	stand 5l: group cut (winter 1991-1992) (70-year stand of *Quercus rubra* & *Fagus sylvatica*, used as a picnic place during 1970-80)
time period	1992–2002
goal	Can we regenerate degenerated forest soils by changing tree species, adding fertilizers or the introduction of anecic earthworms?
set-up	- planted in 1992 - 180 *Fraxinus excelsior* in 4 blocks, planting distance 1.5 m - block = 3 experimental groups, 15 trees/group, control – fertilizer – fertilizer+earthworms - fertilizer (P, K, Ca, Mg): 500 g dolomite, 100 g slags, 100 g kieserite – mixed with the soil from the planting pits - introduction earthworms: 40 adults = 20 anecic (10 *Lumbricus terrestris*, 10 *Nicodrilus longus*) + 20 endogeic (mix van *Aporrectodea caliginosa*, *Aporrectodea rosea*, *Allolobophora limicola*) - plants with naked roots, pits ø 40 cm, 40 cm depth - 1 m² around each ash = soil sample plot: 2 nested subplots of 0.5 m² (sampling in and outside of the planting pit)
data collection	<u>TREES</u> - height, growth, mortality: yearly (except for 1999) - 2002: 2 random trees harvested per treatment and block (24 trees in total) – aboveground biomass: leaf, branch, stem – nutrients in leaves upper third crown/lower 2/3 crown <u>SOIL/LITTER</u> - herb layer removed - ectorganic layer gathered - stability aggregates: sampling upper 10 cm in the 2 subplots - soil samples 0-10 cm, 10-40 cm, 40-70 cm <u>EARTHWORMS</u> - part 1: sorting of the ectorganic layer - part 2: formaline solution (= 37 % formaldehyde in water) on the 2 subplots (2 x 10 l 0.05 % solution, 2 x 10 l 0.1 % solution, time interval = 10 min) - part 3: soil sample of 20 dm³, 48 h in a solution of 10 l water + 100 cm³ Natriummetafphosphate ($Na_6(PO_3)_6$) + 800 ml formaline, wet sieved

	- biomass earthworms (g/m^2) = 10 m_1 + 2 m_2 + 10 m_3 - juveniles, non-identifiable earthworms or part sorted into the other species groups pro rata <u>(CHEMICAL) ANALYSES</u> - leaf samples and litter dried and ground - total N: Kjeldahl - nitrate-N/ammonium-N: colorimetric after extraction with 1 % KCl - pH_{KCl}: glass electrode in 1 mol/l K Cl solution - concentration K, Ca, Mg, Na: Varian SpectrAA 220 spectrophotometer – exchangeable after extraction with 0.1 mol/l $BaCl_2$ – total after destruction with H-perchlorate – Ca with N2O-acetylene flame / rest with air-acetylene flame – solution with 10 % CsCl - concentration total P: colorimetric - OM: Walkley & Black + Kalra & Maynard - Stability aggregates: sieve 10 mm, air-dry – aggregates sieved on 2000 μm, 250 μm, 53 μm (5 minutes soaked in demineralised water) – manual sieving (50 x 3 cm up and down in 2 minutes) – remaining soil dried at 60°C and weighted
remarks	location and scheme set-up in Beckers_2002_th

RESULTS

<u>TREES</u>

- Height growth:
  - control: little growth in year 1&2, dead afterwards
  - fertilizer (+worms): good growth, fertilizer better in the first 2 years, + worms afterwards (significantly better only in year 4&5)
- biomass after 10 year
  - higher for fertilizer+worms, not significantly
- leaf nutrient concentration
  - N, P, Na, K larger for fertilizer+worms, not significantly
  - Ca, Mg lower for fertilizer+worms, not significantly

<u>ECTORGANIC LAYER</u>

- control plots: no difference in pH or concentration in or outside planting pit
- pH
  - higher in treated plots (in and outside pit)
  - pH higher in planting pit than outside for fertilizer and fertilizer+worms
- nutrient concentration
  - no significant difference between treatments in the planting pit
  - oustide the pit: Mg sign higher in treated plots, K sign higher in fertilizer compared to control (fertilizer+worms intermediate)
  - concentration in > concentration outside pit for Mg (fertilizer, fertilizer+worms), Na (fertilizer)

<u>SOIL: total concentration</u>

- 0–10 cm
  - control plots lower conc P, Ca, Mg + smaller pH (in the pit)
- 10–40 cm
  - control plots lower conc Ca, Mg + smaller pH (in the pit)
- 40–70 cm
  - control plots smaller pH (in the pit)
- no significant differences outside the planting pit
- differences between in and outside the planting pit
  - no differences for the control plots
  - fertilizer
    - 0–10 cm: **pH higher** in the pit
    - 10–40 cm: OM, N, Ca, Mg, **pH higher**

        - 40–70 cm: P, Mg, **pH higher**
    - fertilizer + worms
        - 0–10 cm: **Ca**, Mg, **pH higher**
        - 10–40 cm: N, Na, K, **Ca**, Mg, **pH higher**
        - 40–70 cm: N, **Ca**, **pH higher**

SOIL: exchangeable concentration (in the planting pit)

- Ca, Mg lower in control
- NO_3-N lower in fertilizer than in control, intermediate in fertilizer+worms
- Na higher in fertilizer than in control, intermediate in fertilizer+worms

SOIL: aggregates

- fractions do not differ between treatments (in and outside the planting pit)
- larger fraction of large aggregates oustide the planting pit, smaller aggregates more in the pit

EARTHWORMS

- 4 species after 10 years
    - epigeic species
        - *Dendrobaena octaedra*: treatment/control, in/out planting pit
        - *Lumbricus rubellus*: treatment, in/out planting pit
    - endogeic species
        - *Aporrectodea caliginosa*: treatment, in planting pit
        - *Octolasion cyaneum*: 2 pits of the fertilizer treatment
- In the planting pit: BM significantly larger in the treated plots
- BM in the fertilizer plots significantly larger in the pits

CONCLUSIONS

- Adding fertilizers in the planting pit enables planting ash in acidified forest soils. (Nonetheless, the concentrations of P, K, Ca in the ash leaves are suboptimal, which might be negative for the survival of the trees in the long run.)
- The additional introduction of earthworms might prolong and intensify the positive effect of the fertilizers. (Initially, N might be fixed because of the development of the earthworm population; afterwards, the nutrients might be better accessible and a larger soil volume can be used by the roots.)
- Adding fertilizers increases the concentrations of Ca and Mg, and the pH. No additional effect of the addition of earthworms.
- Adding earthworms did not affect the soil structure (possibly because of the low number of endogeic species and the absence of anecic species).
- A higher earthworm biomass in treated plots. Absence of anecic earthworms possibly because of low initial pH: *Nicodrilus longus* (min pH 4.91), *Lumbricus terrestris* (min pH 3.93). Biomass larger in the planting pit in the fertilizer treatment. Adding relatively acid-tolerant endogeic species may be more successful than adding less acid-tolerant anecic species.
- Soil-improving effect of ash not visible after 10 years (ash litter production marginal when compared to the litter of the surrounding species).