SUJET 1. Quel peut être l'impact à l'échelle de l'écosystème d'une invasion biologique dans le sol?

Title: Global worming: massive invasion of North America by earthworms revealed

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Les documents suivants sont tous extraits d'articles scientifiques traitant des conséquences de l'invasion en cours des forêts nord américaines par des espèces exotiques de vers de terre, provenant d'Europe. Ces études ont comparé des placettes plus ou moins fortement impactées par l'invasion.

DOC 1

Biogeographic studies and analyses of earthworm distribution suggest that native earthworm species are rare in the northern forests of North America, presumably because they were eliminated from the region during the last glacial period and were slow to recolonize the area after the glaciers receded (Reynolds 1994; James 1995). Most earthworms that occur in northern forests in North America are exotic species, and their recent invasion into new areas has caused marked changes in forest floor characteristics and nutrient dynamics (Scheu and Parkinson 1994a, 1994b; Alban and Berry 1994; Groffman and Bohlen 1999). Although earthworms are a natural component of many forest ecosystems, it is not known how their invasion of new sites will affect nutrient cycling in the short and long term.

Earthworm : ver de terre

Forest floor : litière, horizon organique de surface des écosystèmes forestiers

Extrait d'introduction de : Bohlen et al, 2004. Ecosystem Consequences of Exotic Earthworm Invasion of North Temperate Forests. Ecosystems 7: 1-12

DOC 2

Impacts on soils

Upon invasion, earthworms alter the structure of soil horizons, availability of nutrients, and soil biota. The type and magnitude of these impacts vary with the species of earthworm and characteristics of the soil. Colonization by litter-dwelling, epigeic earthworm species such as *Dendrobaena octaedra* physically disrupts the separation of organic layers by mixing of F (O_e) and H (O_a) materials, but leaves the litter (L or O_i) layer relatively intact and has little impact on the structure of the mineral soil (McLean and Parkinson 1997a, b). Soil dwelling endogeic, epi-endogeic and deep-burrowing anecic earthworm species (e.g. *Aporrectodea* sp., *Lumbricus rubellus*, and *L. terrestris*, respectively) consume the surface organic horizon, mixing surface litter into the upper mineral soil horizons, to an average depth of 25–30 cm (Lee 1985; Edwards and Bohlen 1995). Therefore, the result of multi-species earthworm invasion is conversion from a mor organic horizon structure (consisting of O_i, O_e, O_a subhorizons) over a thin A horizon and well-developed E horizon below, to a mull structure similar to a previously farmed plow layer (only O_i subhorizon present) over a relatively deep (up to 25 cm) organic-rich A horizon (Langmaid 1964; Shaw and Pawluk 1986; Alban and Berry 1994). This post-earthworm structure is similar to soils found under non-acid hardwood forests in northern Europe, where the lumbricid species of earthworms invading North America are native (Kubiena 1948; Bal 1982; Ponge and Delhaye 1995).

litter-dwelling : vivant dans la litière

soil-dwelling : vivant dans le sol organo minéral

deep-burrowing : qui creuse des galeries profondes

hardwood forests : forêts à base d'angiospermes (par opposition aux forêts de conifères qui sont des gymnospermes)

Extrait de : Frelich et al, 2006. Earthworm invasion into previously earthworm-free temperate and boreal forests. Biological Invasions 8: 1235-1245

DOC 3

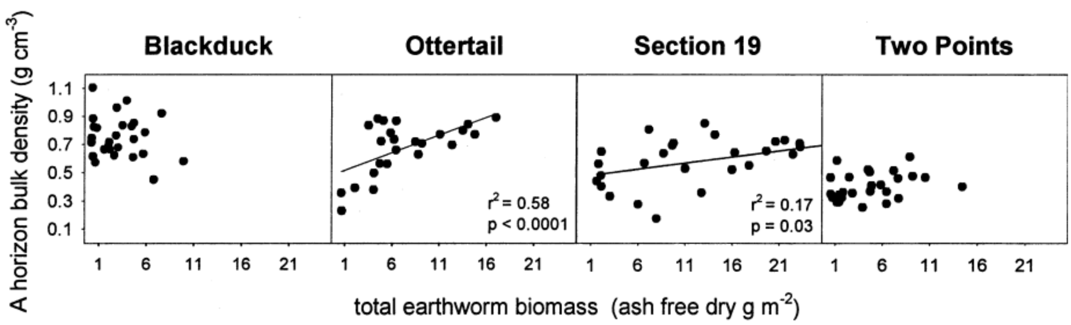

Figure 3. Scatter plots of A horizon bulk density in relation to mean total earthworm biomass in each study site. $n = 27$ in each site except Ottertail where $n = 24$.

bulk density : densité apparente

Hale et al 2005. Effects of European Earthworm Invasion on Soil Characteristics in Northern Hardwood Forests of Minnesota, USA

DOC 4

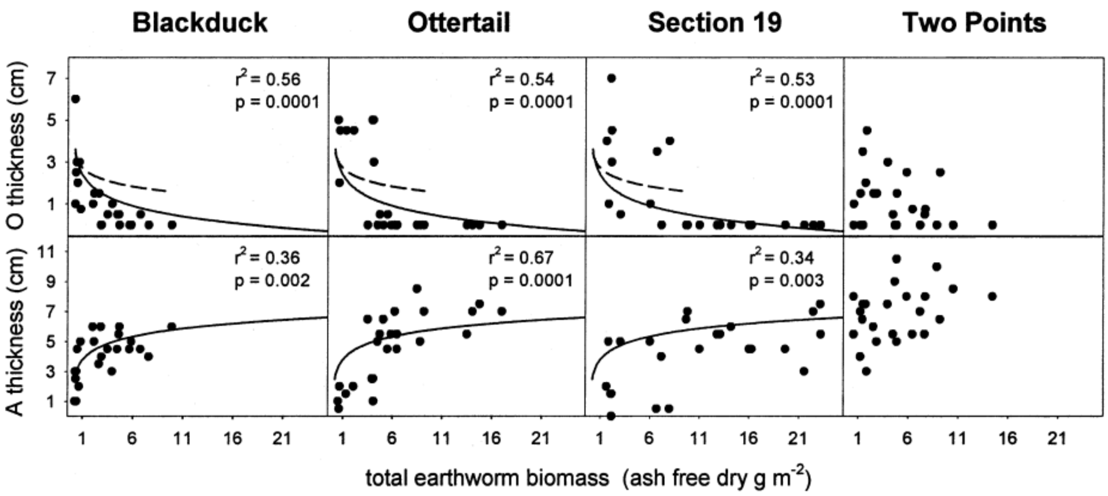

Figure 4. Scatter plots of 1999 O and A horizon thickness in relation to mean total earthworm biomass in each study site. Fitted relationships with solid lines include all data points, $n = 24$ in each site. For comparison, O horizon fitted relationships with all zero values deleted are provided (*dashed lines*), however, only for the Blackduck site is this relationship significant ($r^2 = 0.45$, $P = 0.004$).

O horizon : horizon de litière

A horizon : premier horizon organo minéral

Hale et al 2005. Effects of European Earthworm Invasion on Soil Characteristics in Northern Hardwood Forests of Minnesota, USA

DOC 5

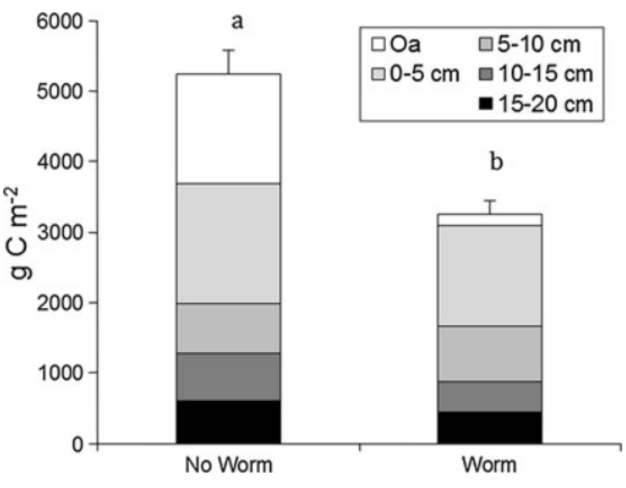

Fig. 1 Soil carbon pools in summer 2006 for 0–20 cm soil of earthworm-free plots and plots with invasive earthworm communities dominated by *Lumbricus* spp. at Arnot Forest, New York. *Error bars* indicate standard errors, and *different letters* indicate significant differences between no worm and worm-invaded plots

Fahey et al, 2013. Earthworms, litter and soil carbon in a northern hardwood forest. Biogeochemistry 114: 269-280

DOC 6

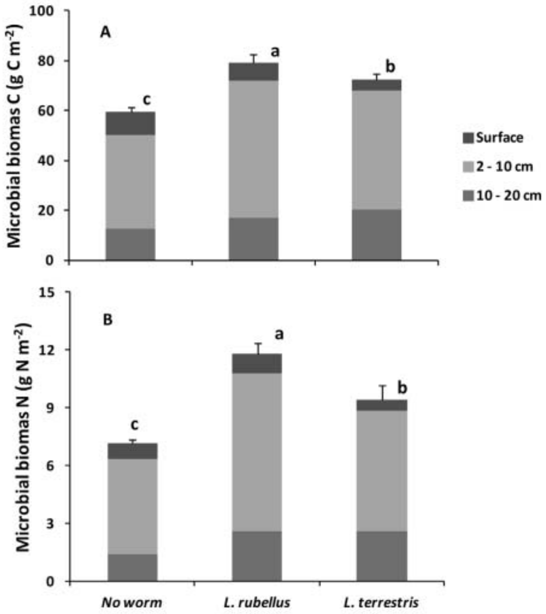

Fig. 2. Microbial biomass carbon (A) and nitrogen (B) at three depths in reference (No worm) plots and in earthworm colonized plots dominated by *Lumbricus rubellus* (L. rubellus) and *L. terrestris* (L. terrestris) at the Arnot Experimental Forest, NY. Values are means ± standard error over four sampling dates between May 2008 and October 2010 ($n = 24$ for each depth). Different superscripts indicate statistically significant differences at $p < 0.05$. Specific treatment differences at different depths are presented in Table 3.

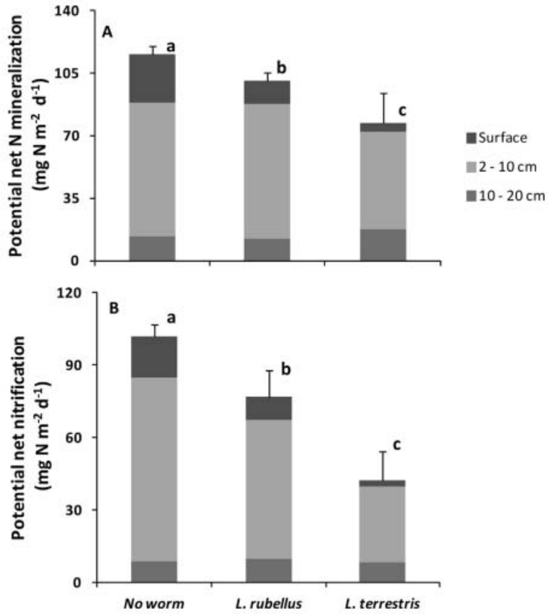

Fig. 3. Potential net N mineralization (A) and nitrification (B) at three depths in reference (No worm) plots and in earthworm colonized plots dominated by *Lumbricus rubellus* (L. rubellus) and *L. terrestris* (L. terrestris) at the Arnot Experimental Forest, NY. Values are mean ± standard error over four sampling dates between May 2008 and October 2010 ($n = 24$ for each depth). Different superscripts indicate statistically significant differences at $p < 0.05$ except that the difference in potential net N mineralization between no earthworm plots and plots without *L. terrestris* is different at $p < 0.10$. Specific treatment differences at different depths are presented in Table 3.

La biomasse microbienne est mesurée par fumigation d'échantillons de terre au chloroforme, ce qui détruit les cellules et libère leur contenu. Le C et l'N solubles sont mesurés dans des extraits d'échantillons fumigés et non fumigés et la différence entre les deux permet d'estimer la biomasse microbienne. La minéralisation et nitrification potentielles sont estimées au laboratoire sur des échantillons de terre incubés.

Groffman et al, 2015. Earthworms increase soil microbial biomass carrying capacity and nitrogen retention in northern hardwood forests. Soil Biology and Biochemistry 87, 51-58

DOC 7

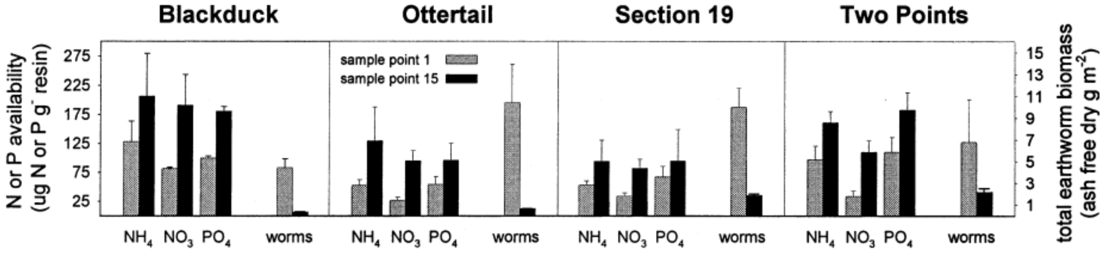

Figure 6. Paired comparisons of mean N (as ammonium and nitrate) and P (as phosphate) availability and total earthworm biomass at opposite ends of the sample grid in each site, $n = 6$ in each site. All comparisons are significant at $P \leq 0.02$.

Hale et al 2005. Effects of European Earthworm Invasion on Soil Characteristics in Northern Hardwood Forests of Minnesota, USA

DOC 8

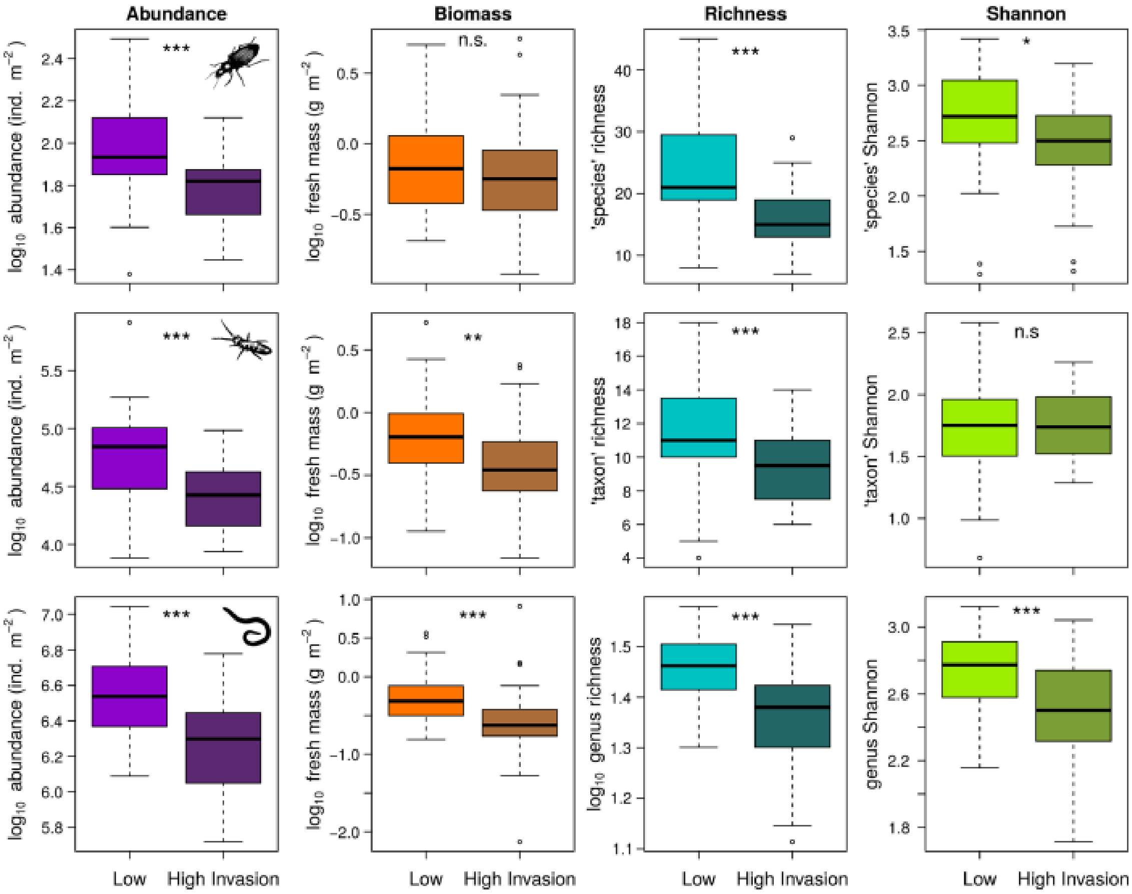

Figure 1. Boxplots showing differences in abundance, biomass, richness (species, taxon and genus richness) and Shannon index (left to right columns) of soil fauna size groups (macrofauna, mesofauna, microfauna, top to bottom rows) in low (left, bright color shade) and high invasion (right, dark color shade) sites across the four northern North American forests (n=78–80, Table 1). Asterisks and 'n.s.' show significance levels ('n.s.' not significant, $p > 0.05$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$) of associated linear mixed effects models with 'forest' as random effect. Table 1 for detailed results of linear mixed effects models. Note that due to transformation of response variables, not all y-axes are on a comparable scale. Also, variables have been scaled to SI units where possible; for information on the original area of the different sampling techniques, please refer to the methods. Animal silhouettes are from PhyloPic.org (nematode) and Florian Schneider (collembola and beetle).

Jochum et al, 2021. Earthworm invasion causes declines across soil fauna size classes and biodiversity facets in northern North American forests. Oikos 130: 766-780

On en parle aussi ici : https://www.nationalgeographic.com/animals/article/earthworms-invasive-north-america-hurt-insects !

DOC 9

Impacts on plant communities

The cumulative impact of earthworm invasion on many plant species is likely to be substantial and may result in significant changes in community composition. In uncultivated, mature sugar maple dominated forests of northern Minnesota, earthworm invasion caused significant declines in the diversity and cover of herbaceous plants and abundance of tree seedlings (Fig. 1). Diverse, lush herb communities of spikenard (*Aralia racemosa*), solomon's seal (*Polygonatum pubescens*), bellwort (*Uvularia grandiflora*), nodding trillium (*Trillium cernuum*), large-flowered trillium (*Trillium grandiflorum*), and goblin fern (*Botrychium mormo*) were transformed to simplified communities of only a few species dominated by *Carex pennsylvanica* and *Arisaema triphyllum* (Gundale 2002; Hale 2004) (Fig. 2). There are several possible mechanisms underlying the changes in plant communities during non-native earthworm invasion.

seedling : plantule

lush : verdoyant

Extrait de : Frelich et al, 2006. Earthworm invasion into previously earthworm-free temperate and boreal forests. Biological Invasions 8: 1235-1245

DOC 10

Figure 3. Impacts of European earthworm invasions on North American forests. (a) Base of a sugar maple (*Acer saccharum*) tree in a temperate forest in southern Minnesota, showing loss of the organic horizon and subsequent soil erosion; (b) base of a balsam fir (*Abies balsamea*) tree in a boreal forest in northern Minnesota, showing recession of the forest floor and exposure of roots leading to drought stress; (c) invasion front of common buckthorn (*Rhamnus cathartica*) in an earthworm-infested oak and maple forest in southern Minnesota; (d) *Lumbricus rubellus*, a European earthworm species responsible for consumption of the organic horizon in forests.

Frelich et al, 2019. Side-swiped: ecological cascades emanating from earthworm invasions. Frontiers in Ecology and Environment 17: 502-510