# Non-Native Invasive Earthworms in the Midwest and Eastern United States

## *A Primer*

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Prior to European settlement, earthworms were rare across most of the Midwest and Eastern United States (James 1995). This is presumably because earthworms were slow to recolonize after the last glacial period. Currently, earthworms of European and Asian origin are invading this region with demonstrable effects on soil characteristics and ecosystem functions. Eradicating non-native invasive earthworms (hereafter, "earthworms") is generally not a realistic management goal. Still, understanding how earthworms act as ecosystem engineers will aid land managers in considering how earthworms modify local effects of climate change and management actions on natural ecosystems. Additionally, where earthworms have not yet invaded, managers can take efforts to avoid their introduction (e.g., minimizing cross-site movement of soil and plant litter).

Given that earthworms are often associated with decreased soil compaction and increased soil fertility in agricultural settings, land managers may be understandably confused: *are earthworms—even if invasive—'good' or 'bad' for soils and ecosystem health?* Although benefits may occur in agricultural lands, earthworms can significantly disrupt natural ecosystems. Here, we aim to help managers better understand how earthworms may be affecting the health and resiliency of their site in natural systems.

## Distribution and Ecological Grouping of Invasive Earthworms in the Region

Earthworms of European origin first invaded the United States several hundred years ago and are widespread (but not ubiquitous) across the Midwest and Northeast. Asian invasive jumping worms[1] are more recent invaders (unknown, but likely mid-late 1800s) and are common across the Northeast with an invading front moving west but yet to cross the Rocky Mountains (Chang et al. 2021). European earthworms can live for multiple years, while Asian jumping worms have an annual life cycle and can grow more quickly and at higher densities. Overall, earthworm biomass and density tend to be greater closer to human disturbances such as roadways (Shartell et al. 2015, McCay and Scull 2019).

All earthworms can be loosely categorized into three ecological groups characterized by distinct feeding and burrowing activity that differentially affect soils (Fig. 1).[2] **Epigeic** earthworms, such as Asian jumping worms of the *Amynthas* genus, reside in the upper organic layer of the soil and consume litter but do not significantly mix plant litter with mineral soil. **Endogeic** earthworms reside in the organic layer and upper mineral soil, and both consume

[1] There are 16 species of pheretimoid earthworms within the family Megascolecidae that have invaded North America to date. Collectively, these earthworm species are colloquially referred to as jumping worms, wriggling worms, crazy worms, or snake worms (Chang et al. 2021).

[2] These groups are useful for broadly characterizing distinct earthworm effects on soils, but many species exhibit traits of two or more groups. For example, many earthworm species are referred to as epi-endogeic as they function in many ways like both epigeic and endogeic species.

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litter and enhance mixing of plant litter and mineral soil. **Anecic** earthworms, such as the European species *Lumbricus terrestris*, form deep (up to 1-2 meters) vertical burrows and move significant amounts of surface litter deep into mineral soil, resulting in significant litter mixing along with litter consumption.

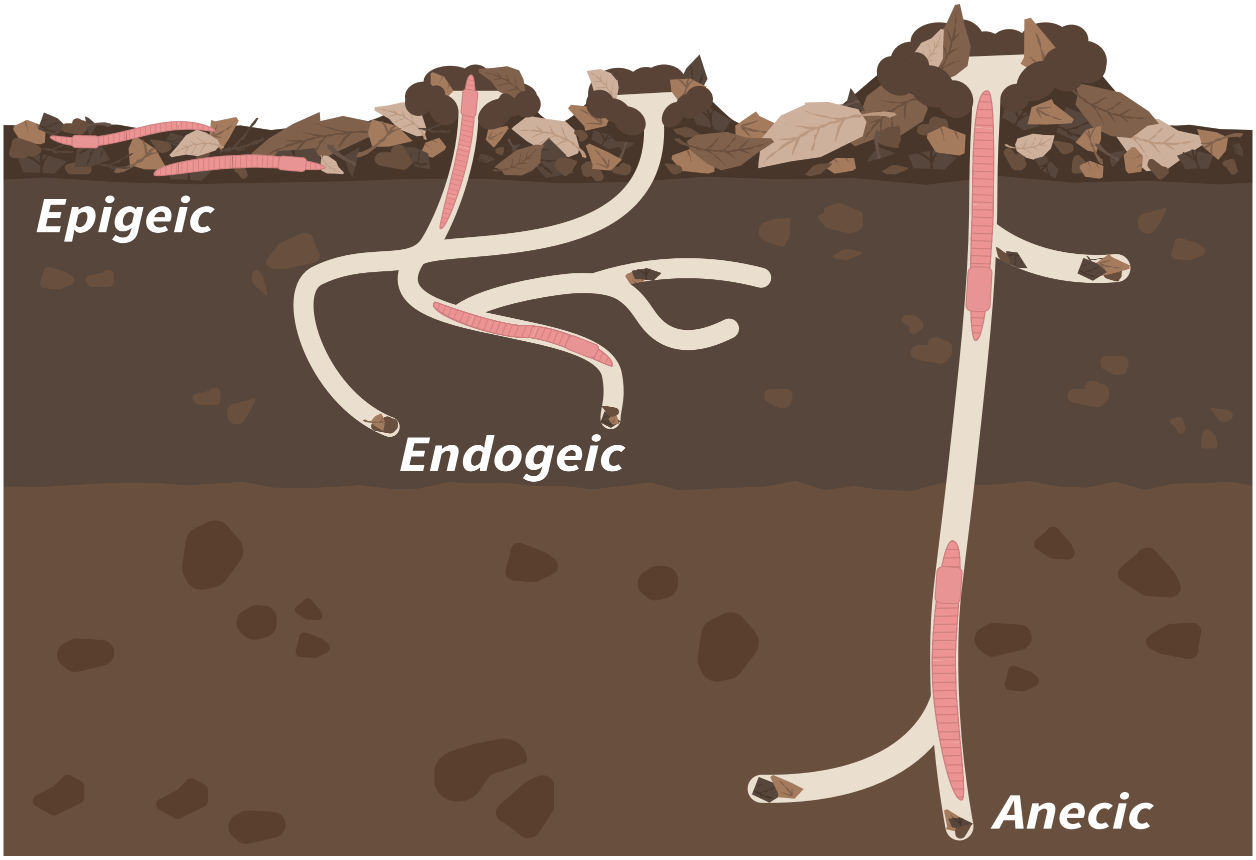


**Figure 1—**Illustration of earthworm ecological groups.

## Effects on Soil Physical and Chemical Properties

Earthworms have long been recognized to be important ecosystem engineers, yet many of the specifics of earthworm effects on soil and ecosystem properties are still not fully understood. Most research has been carried out in short-term laboratory experiments, and there is a need to better understand the long-term effects of earthworms in more realistic field conditions. Earthworm effects are better studied in agricultural settings and forests compared to grasslands (Qiu and Turner 2017). European earthworm effects in North America are also better studied compared to the effects of Asian jumping worm species (Chang et al. 2021). The ecological impacts of earthworms vary by ecological group and species. For example, *L. terrestris* and *L. rubellus* (epi-endogeic) have more detrimental effects on ecosystem processes compared to other species (e.g., *Dendrobaena spp.*).

Earthworms can have dramatic effects on physical soil structure. In contrast to agricultural systems which are prone to soil compaction, in natural ecosystems earthworms increase soil bulk density across the soil profile. This is because in natural systems earthworms decrease organic horizon thickness, reduce abundance of native soil invertebrates, and burrowing and casting activities can facilitate soil aggregation (Frelich et al. 2006). Asian jumping worms are particularly distinct from European earthworms in their effects on surface soils. Jumping worms form granular casts that carpet the forest floor in a thick layer of loose macroaggregates, altering soil porosity and dampening soil temperature variability.

### Casting

The release of earthworm excrement into the soil is called casting. European and Asian earthworms have quite different types of castings, although how these differences affect long-term soil carbon storage is not yet well understood.

Earthworm activity also speeds up nutrient cycling and reduces fungal dominance (Wardle 2002). While nutrient availability can increase with earthworms due to redistribution of soil organic material, nutrient leaching and loss also increases (Frelich et al. 2006, Qiu and Turner 2017). Over the long term, earthworms generally decrease soil fertility in natural ecosystems (Frelich et al. 2019).

## Effects on Soil Carbon

While earthworm effects on soil carbon vary across sites, in general earthworms do not significantly alter total soil carbon storage (Lubbers et al. 2013, Ferlian et al. 2020). However, some evidence suggests earthworm activity can increase the fraction of soil carbon that persists for long periods of time (Zhang et al. 2013, Angst et al. 2019). If and where earthworms facilitate greater soil carbon persistence, this could benefit carbon mitigation given that soil carbon is the largest terrestrial reservoir of carbon. In contrast, earthworm activity can increase greenhouse gas emissions from the soil, although such effects tend to be short-lived and weaker in natural ecosystems compared to agricultural systems (Lubbers et al. 2013). In sum, earthworms do not have large effects on total soil carbon storage but can alter how carbon is cycled through the soil.

Most visibly, earthworms can greatly affect the distribution of carbon throughout the soil profile. Earthworms, particularly endogeic and anecic species, redistribute organic matter from the litter layer to mineral soils. For example, in a deciduous Minnesota forest with sandy loam soils, the invasion of earthworms led to a near complete disappearance of the forest floor and development of an A horizon after a decade. Still, total soil carbon (to 50 cm depth) decreased only slightly at this site (Alban and Berry 1994).

## Effects on Ecosystem Biodiversity

Earthworms can have detrimental effects on both belowground and aboveground biodiversity. They generally decrease soil biodiversity and invertebrate abundance (Ferlian et al. 2018, McCay and Scull 2019). Aboveground, earthworm invasion can shift plant community composition, favoring sedges and graminoids at the expense of native herbs in the understory, for example. Plant diversity commonly decreases, while many invasive plants such as garlic mustard (*Alliaria petiolata*), Japanese barberry (*Berberis thunbergii*), and European buckthorn (*Rhamnus cathartica*) can increase in abundance (Chang et al. 2021). Earthworms can facilitate buckthorn germination by reducing forest floor thickness and soil moisture (Roth et al. 2015). Earthworms have been associated with sugar maple (*Acer saccarhum*) decline across much of the region and suppressed tree regeneration. Site factors including soil characteristics, land-use history, earthworm and plant species identity, and deer browse pressure interact to influence effects of earthworms on local biodiversity.

## Effects on Ecosystem Vulnerability

Earthworms have multiple, interacting effects on ecosystem functioning. Earthworms disrupt soil physical structure, food webs, and nutrient cycling. Due to complex interactions between both direct and indirect effects of earthworms on natural ecosystems, climate impacts and vulnerabilities for a given site are difficult to predict.

Still, there are some common patterns of earthworm effects across sites. Earthworm effects on natural ecosystems are generally greater in forests compared to grasslands, especially in forests originally characterized by a thick organic horizon. Sites without a history of plowing or with higher deer populations are also more susceptible to the negative effects of earthworms (Bohlen et al. 2004a p. 20, Frelich et al. 2006, Qiu and Turner 2017). Earthworms commonly decrease plant productivity and microbial and plant diversity, and also can significantly shape plant community composition. In the understory, earthworms negatively affect native species, and high deer browse pressure exacerbates this effect. Low rates of plant reproduction over multiple generations can deplete the native seed bank, posing a major challenge to recruiting and sustaining native plant species (Nuzzo et al. 2015). At the same time, the presence of earthworms can create conditions better suited to invasives, making it more difficult to manage invasive plants.

Earthworms can interact with climate change to shift forest plant community composition and structure. For example, earthworms can increase drought sensitivity of sugar maple (Larson et al. 2010), while other species better adapted to dry conditions and a minimal litter layer, such as oaks, may become more dominant (Frelich et al. 2017). More broadly, earthworm-induced crown diebacks result in smaller-statured forests that can also better withstand wind disturbances (Frelich et al. 2019).

Earthworms generally increase drought risk. When earthworms reduce soil organic horizon thickness, soil drying increases. Earthworm disruption of root and fungal networks also decreases the plant community's resistance to drought. Reduced organic horizon thickness reduces fuel loads, which reduces the ability of a site to carry fire. Collectively, these effects increase the vulnerability of worm-invaded ecosystems to climate change impacts and disturbances. Warmer temperatures due to climate change are also expanding the potential range of earthworm invasion to northern locations.

## Land Management Considerations for Natural Ecosystems

For sites not yet invaded by earthworms, efforts can be taken to "slow the spread" and reduce the likelihood of invasion including:

- Washing vehicles and other equipment if moving from an invaded to an uninvaded site. Soil and debris on tire tread and other equipment can contain worms and their cocoons, which can be unknowingly transported to an uninvaded site.
- Using litter, mulch, or soil from an uninvaded site that has been confirmed to be free to non-native earthworms. Heating litter, mulch, or soil to 105 °F for at least three days or freezing for at least one week can reduce the presence of invasive worms.
- Using seedlings and saplings for planting that are definitively free of non-native earthworms.
- Educating anglers on the impacts of invasive earthworms and providing waste bins at fishing sites to throw away worms, as freshwater angler activity is one of the biggest factors in expanding the range of invasive earthworms.

For sites currently invaded by earthworms, recognizing how earthworm presence affects management can guide discussions of which management actions are more likely to succeed at a given site. Earthworms can shape both the efficacy and outcome of land management actions. Key considerations for land management in the presence of earthworms include:

- Reducing or excluding (via fencing) deer populations can reduce earthworm populations (Reed et al. 2023).
- Reduced organic horizons and fuel loads can make it more difficult for managers to successfully carry out prescribed burns (Frelich et al. 2019). However, if a site can successfully carry fire, prescribed burns may help control earthworm populations (Ikeda et al. 2015). Prescribed fire is more likely to control epigeic earthworms compared to endogeic or anecic earthworms, although more research is needed.
- Actively managing the seed bank to promote native species, including direct seeding of natives, may be a viable strategy to maintain local native plant populations given the direct negative effect earthworms can have on the seed bank. Seed bank management can also help suppress invasive species, particularly in sites with low deer populations (Bohlen et al. 2004b, Nuzzo et al. 2015).
- Earthworms increase the competitive ability of many invasive plants. However, successful removal of invasive plants can reduce invasive earthworm biomass, thereby reducing the deleterious local effects of earthworms (Madritch and Lindroth 2009, Coyle et al. 2017).
- Earthworms increase drought risk, so planting and managing for more drought-tolerant species can decrease ecosystem vulnerability in the presence of earthworms.

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## *More Information*

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