



10 Invasive Plant Impacts on Soil Macrofauna through Allelopathy and Environmental Modification

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Introduction

Soil macrofauna taxonomic groups such as annelids (earthworms), arthropods (insects and crustaceans) and molluscs (gastropods/snails) play an essential role in soil ecosystems (van Hengstum *et al.*, 2014; Zulu *et al.*, 2022; Mamabolo *et al.*, 2024). These organisms help convert organic matter into forms that can be utilized by plants, ultimately supporting soil fertility (Sofu *et al.*, 2020; Mamabolo *et al.*, 2024). They influence soil structure, organic matter decomposition, nutrient cycling, soil aeration and ecosystem functioning (van Hengstum *et al.*, 2014; Ibrahima *et al.*, 2017). Thus, their presence and diversity are integral to maintaining soil fertility and productivity, making them important bioindicators for assessing soil health (Rousseau *et al.*, 2013; Sofu *et al.*, 2020). Soil macrofauna physically and biologically alter the soil structure, enhancing the permeability of the

soil and improving water infiltration (Zhou *et al.*, 2022). Besides, they contribute to the creation of microhabitats for other organisms, promoting biodiversity conservation (Huerta and van der Wal, 2012). For instance, earthworms, through their burrowing and feeding activities, not only recycle nutrients but also create channels in the soil that facilitate the movement of water and air (Ibrahima *et al.*, 2017; Yang *et al.*, 2024).

Soil macrofauna – ants, termites and beetles – are involved in the breakdown of organic matter, including plant litter and animal remains, thereby playing a role in nutrient cycling (Jouquet *et al.*, 2011; Ibrahima *et al.*, 2017; Mamabolo *et al.*, 2024). The presence and activity of these macrofauna can also influence the abundance and diversity of soil microorganisms, further enhancing nutrient cycling (Zhou *et al.*, 2022). Research conducted by Liu *et al.* (2020) and Singh *et al.* (2019) reveals

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Table 10.1. Some common examples of soil macrofauna.

Common name	Scientific name	Family name
Common earthworm	<i>Lumbricus terrestris</i>	Lumbricidae
Termites or white ant	<i>Macrotermes bellicosus</i>	Termitidae
Formosan termite	<i>Coptotermes formosanus</i>	Rhinotermitidae
Red wood ant	<i>Formica rufa</i>	Formicidae
Garden snail	<i>Cornu aspersum</i>	Helicidae
African millipede	<i>Archispirostreptus gigas</i>	Spirostreptidae
Sacred scarab/beetle	<i>Scarabaeus sacer</i>	Scarabaeidae
Woodlouse/sow bug	<i>Armadillidium vulgare</i>	Armadillidiidae
Springtail	<i>Folsomia candida</i>	Hypogastruridae
African centipede	<i>Ethmostigmus trigonopodus</i>	Scolopendridae

that earthworms are particularly effective at enhancing soil aggregation, which improves the structural stability of the soil. This effect is also seen in termite species, which build intricate tunnel systems that help aerate the soil and facilitate nutrient movement (Black and Okwakol, 1997; Sileshi *et al.*, 2010; Jouquet *et al.*, 2011, 2018; Ali *et al.*, 2013). [Table 10.1](#) provides some common examples of soil macrofauna species.

In addition to earthworms ([Fig. 10.1](#)) and termites, other arthropods like beetles and ants contribute to soil structure by burrowing and mixing soil layers, leading to improved soil aeration and reduced compaction. These soil macrofauna also contribute to the formation of soil aggregates, which are crucial for maintaining soil porosity and preventing erosion (Sofa *et al.*, 2020; Mamabolo *et al.*, 2024). Moreover, ants and termites play a role in regulating pest populations by preying on insects and other invertebrates that could harm crops and other beneficial plants (Bohlen *et al.*, 2004).

Despite their importance in ecosystems, soil macrofauna are negatively impacted by invasive plant species in addition to other numerous threats (Blakeslee *et al.*, 2011). Native vegetation cover is considered to be among the factors influencing soil macrofauna (Wiatrowska *et al.*, 2024). But, the invasive plants alter native vegetation communities (i.e. composition and structure), transforming the habitat quality because they modify soil physicochemical properties, most often exerting a

directional effect on soil macrofauna (Jesse *et al.*, 2020; Wiatrowska *et al.*, 2024). Thus, invasive plants may pose a significant ecological threat, not only through their disruption of native plant communities but also via their profound impacts on soil health and ecosystem functioning (Stiers *et al.*, 2011; Wiatrowska *et al.*, 2024). They impact soil macrofauna by altering soil chemistry, nutrient availability (or nutrient cycling), microbial communities (Gwate *et al.*, 2021) and organic matter dynamics ([Table 10.2](#)). For instance, some invasive plants often produce allelopathic compounds or allelochemicals that increase bacterial diversity but simultaneously disrupt the balance of soil macrofauna vital for nutrient cycling and plant health (Ojija and Manyanza, 2021; Torres *et al.*, 2021; Ojija *et al.*, 2024). Garlic mustard (*Alliaria petiolata*), for example, was claimed to suppress beneficial mycorrhizal fungi, undermining native plant resilience and soil macrofauna (Flaherty *et al.*, 2024; Nunez-Mir and McCary, 2024).

Additionally, invasive plant litter and root exudates modify decomposition and nutrient mineralization processes, often slowing the release of essential nutrients like nitrogen and phosphorus (Ojija and Manyanza, 2021). This can lead to a reduction in soil nitrification rates, further constraining native species and delaying ecosystem recovery (Ehrenfeld, 2010; Afzal *et al.*, 2023). Physical soil characteristics are also affected, with species such as black wattle (*Acacia mearnsii*) degrading soil structure and reducing

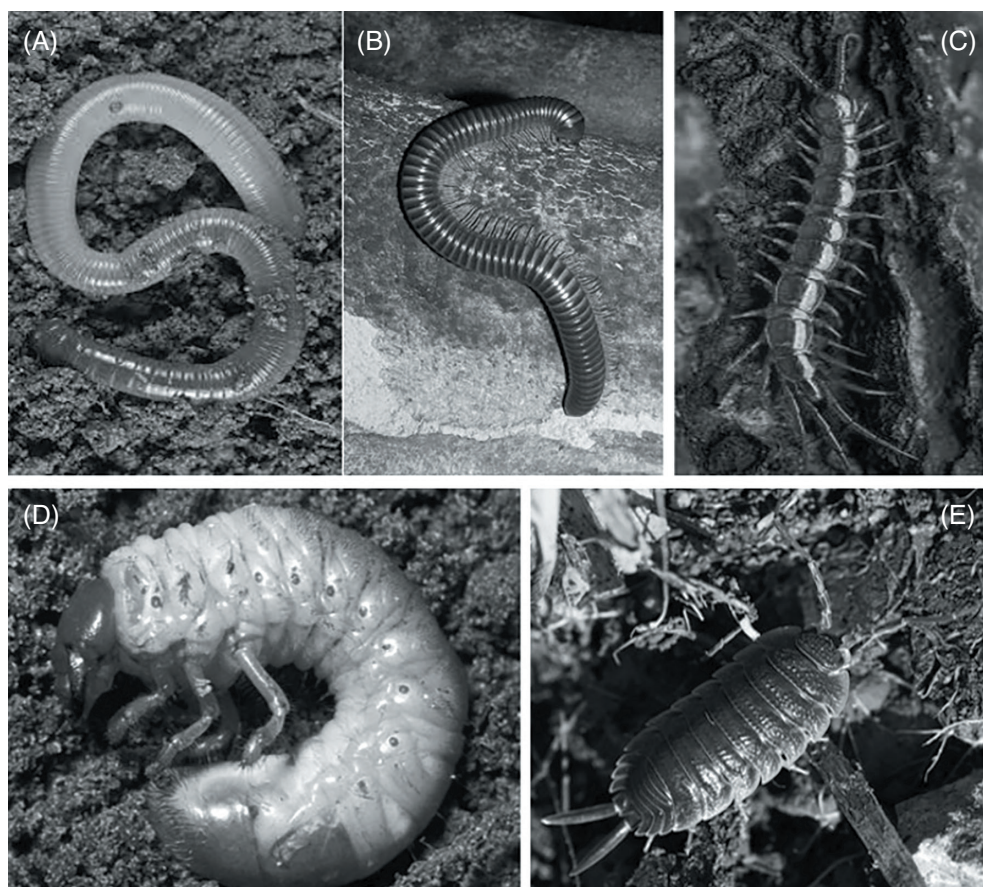


Fig. 10.1. Some examples of soil macrofauna: (A) earthworm (*Lumbricus terrestris*), (B) millipede (*Eumillipes* sp.), (C) centipede (*Scolopendra* sp.), (D) beetle larva (*Scarabaeidae* sp.) and (E) sowbug or woodlouse (*Porcellio scaber*).

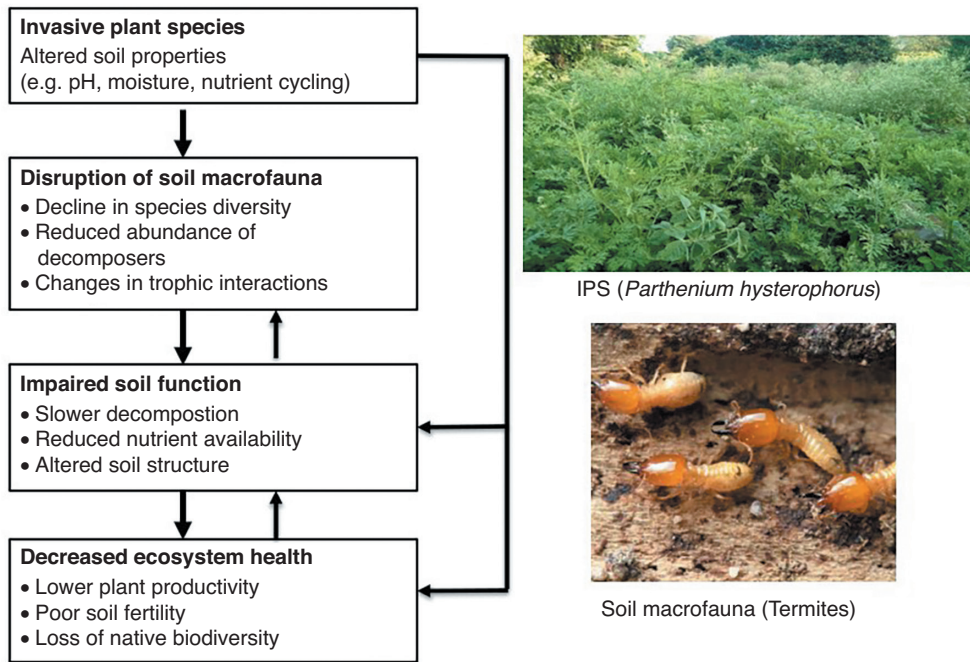
organic matter, which diminishes soil fertility and agricultural productivity (Gwate *et al.*, 2021; Lusizi *et al.*, 2024). These biological and physical transformations generate feedback loops that favour the continued dominance of invasive plants, reduce soil macrofauna biodiversity and compromise ecosystem services (Vilà *et al.*, 2011; Aloo *et al.*, 2013; Coakley and Petti, 2021). The disruption and decrease of soil macrofauna populations can lead to long-term declines in soil health and ecosystem stability (Ibrahima *et al.*, 2017; Yang *et al.*, 2024). Thus, as invasive plants continue to expand their range due to climate change and human activity (Müller-Schärer *et al.*, 2004; O'Reilly-Nugent *et al.*, 2016; Mavimbela *et al.*, 2018), further studies are needed to understand long-term soil macrofauna

responses and develop sustainable conservation strategies (Blakeslee *et al.*, 2011). Monitoring soil health and soil macrofauna biodiversity in invaded ecosystems can provide valuable insights into ecosystem resilience and inform future restoration efforts. By addressing the impact of invasive plants on soil macrofauna, conservationists can work towards maintaining soil fertility, enhancing ecosystem stability and preserving biodiversity in affected regions (Fig. 10.2).

This chapter delves into the effects of invasive plants on the populations of soil macrofauna, with a particular focus on earthworms, arthropods and gastropod communities. It highlights the direct and indirect impacts of invasive plants, including disruptions to food

Table 10.2. A comparison of soil properties in native and invasive plant-dominated ecosystems, illustrating the impact of invasive plants on soil conditions that affect soil macrofauna.

Soil property	Native vegetation	Invaded vegetation	Source
pH	6.5–7.2	5.5–6.0	Bohlen <i>et al.</i> (2004)
	6.5±6.6	6.4±6.9	Ojija and Manyanza (2021)
Organic matter (%)	4.5–6.0	2.5–4.0	Ibrahima <i>et al.</i> (2017), Yang <i>et al.</i> (2024)
Soil moisture (%)	20–35	10–25	Hendrix <i>et al.</i> (2008)
Electrical conductivity (mS/cm)	0.6±0.7	0.4±0.5	Ojija and Manyanza (2021)
Earthworm density (individuals/m ²)	150–300	50–120	Hale <i>et al.</i> (2005)
Phosphorus (mg/kg)	68.6±73.3	48.1±51.8	Ojija and Manyanza (2021)

**Fig. 10.2.** The relationship between an invasive plant species (IPS) and its effects on soil macrofauna and ecosystem health.

webs, altered litter quality and quantity, and the release of allelopathic compounds that modify soil chemistry. The chapter elucidates various strategies for safeguarding soil macrofauna from the negative effects of invasive plants, such as implementing targeted management interventions, enhancing soil biodiversity monitoring

and adopting ecosystem-based conservation practices. Furthermore, it draws on a rich body of evidence from previous studies to demonstrate the global implications of invasive plants on soil health and biodiversity conservation. By synthesizing insights from diverse ecosystems, the chapter underscores the importance of

integrating soil biodiversity considerations into invasive species management to foster long-term ecological resilience and sustainability.

Impacts of Invasive Plants on Earthworm Populations

Earthworms play a vital role in maintaining soil health by contributing to soil structure, organic matter decomposition and nutrient cycling (Singh *et al.*, 2019; Liu *et al.*, 2020). Through their burrowing activities, they improve soil aeration, enhance water infiltration and stimulate microbial activity, facilitating nutrient release essential for plant growth, yet they are vulnerable to environmental changes induced by invasive plants. The introduction of invasive plants has been shown to disrupt earthworm populations by altering key soil properties such as pH, moisture levels, organic matter availability and microbial communities (Hendrix *et al.*, 2008). These disruptions can have cascading effects on soil ecosystem functioning, influencing nutrient availability, plant growth and broader biodiversity.

One of the primary ways invasive plants impact earthworm communities is through allelopathy, the release of biochemical compounds that negatively affect other organisms (Ojija *et al.*, 2019, 2024; Pyšek *et al.*, 2020). Some invasive plant species produce allelopathic chemicals

that may be toxic to earthworms (Table 10.3), reducing their survival and reproductive rates (Ehrenfeld and Scott, 2001; Rodgers *et al.*, 2008; Nunez-Mir and McCary, 2024). For instance, *A. petiolata*, a widespread invasive plant in North America, produces glycosylates that inhibit the growth of mycorrhizal fungi, an essential component of soil microbial communities (Stinson *et al.*, 2006). Since earthworms rely on decomposed organic material rich in microbial activity, such disruptions lead to reduced food availability, ultimately decreasing earthworm abundance and diversity (Table 10.3). Similarly, *Acacia dealbata* (silver wattle), an invasive tree species in Mediterranean ecosystems, releases phenolic compounds that suppress soil microbial activity, leading to a decline in earthworm populations (Lazzaro *et al.*, 2014).

Invasive plants have also been reported to modify soil chemistry (Table 10.2), creating unfavourable conditions for native earthworm species (Simberloff *et al.*, 2013; Ojija and Manyanza, 2021). For instance, an invasive plant *Lonicera maackii* (Amur honeysuckle) alters soil pH and increases carbon and nitrogen levels, disrupting microbial community structures and making the soil less suitable for some earthworm species (Hale *et al.*, 2005). *Phragmites australis* (common reed), a dominant invasive plant in wetland ecosystems, tends to raise soil salinity and slows organic matter decomposition thereby influencing the decrease of earthworm abundance (Srivastava *et al.*, 2014).

Table 10.3. Some case studies on the impacts of invasive plants on earthworm communities.

Invasive plant	Effects on earthworms	Study location	Source
<i>Alliaria petiolata</i>	Releases glucosinolates that suppress microbial activity, reducing food availability for earthworms	North America	Stinson <i>et al.</i> (2006)
<i>Lonicera maackii</i>	Alters soil pH and nutrient balance, leading to declines in native earthworm species	North America	Hale <i>et al.</i> (2005)
<i>Phragmites australis</i>	Increases soil salinity, reducing earthworm abundance and biomass	Africa, South America, Australia	Srivastava <i>et al.</i> (2014)
<i>Acacia dealbata</i>	Produces phenolic compounds that inhibit microbial activity and reduce earthworm population	Mediterranean ecosystem	Lazzaro <i>et al.</i> (2014)
<i>Fallopia japonica</i>	Reduces fungal biomass, affecting decomposition process and earthworm food availability	Europe	Ehrenfeld (2010)

These chemical alterations not only impact earthworms directly but also influence soil food web dynamics, affecting other organisms dependent on decomposed organic material (Gwate *et al.*, 2021; Lusizi *et al.*, 2024).

A study by Liu *et al.* (2020) assessed the allelopathic effects of invasive asterid species (*Ageratina adenophora*, *Bidens pilosa* and *Erigeron annuus*) on the common composting worm *Eisenia fetida*. The results showed significant physiological stress; that is, reduced body mass and increased oxidative damage in earthworms exposed to these invasive plants compared to native plants (Liu *et al.*, 2020). This supports the novel weapons hypothesis, which suggests that invasive plants produce unique chemical compounds unfamiliar to native soil macrofauna, leading to harmful effects (Liu *et al.*, 2020). On the other hand, Bugiel *et al.* (2018) investigated the effects of *Vincetoxicum rossicum* (dog-strangling vine) in Rouge National Urban Park, Canada. The presence of this invasive species significantly altered soil bacterial communities, which indirectly affected earthworm populations by disrupting their food base and microhabitat conditions (Bugiel *et al.*, 2018). Similarly, *Fallopia japonica* (Japanese knotweed) was reported to reduce soil invertebrate diversity by changing litter quality and soil chemistry, leading to less favourable conditions for detritivores (Ehrenfeld and Scott, 2001; Ehrenfeld, 2010).

In wetlands, *P. australis* was reported to alter soil properties – namely oxygen levels and pH – which can suppress native earthworm species (Srivastava *et al.*, 2014). In addition, *Lythrum salicaria* (purple loosestrife) invasions can negatively affect soil invertebrates including earthworms by shifting soil moisture and litter dynamics according to Blossey *et al.* (2001). Another invasive plant, *Melaleuca quinquenervia*, a problematic tree in Florida's wetlands, was asserted to modify soil hydrology and chemistry to the detriment of native earthworm populations (Martin *et al.*, 2011). Its thick leaf litter and canopy reduce sunlight penetration and water infiltration, which compromises the soil conditions earthworms rely on (Martin *et al.*, 2011).

Another mechanism through which invasive plants impact earthworm populations is by altering soil moisture and organic matter availability (Table 10.2). Many invasive

plants have aggressive growth patterns that lead to changes in litter decomposition rates (Jordan *et al.*, 2008). In Europe, the spread of *E. japonica* has been linked to decline in the availability of organic matter for earthworms and other decomposers because this invasive plant produces dense litter with high lignin content that decomposes slowly (Ehrenfeld, 2010). As a result, earthworm populations decline due to a lack of accessible nutrients. Similarly, research in North American forests has shown a significant reduction in earthworm diversity in areas invaded by *A. petiolata*, affecting forest regeneration by altering soil nutrient cycling (Wolfe *et al.*, 2008; O'Sullivan *et al.*, 2019).

Implications for soil health due to loss of earthworms

The decline in earthworm populations due to invasive plants can have severe ecological consequences and cascading effects on soil health and ecosystem functioning. For instance, a reduction in earthworm density leads to soil compaction, decreased aeration and slower organic matter decomposition, all of which negatively affect soil fertility and plant growth (Hendrix *et al.*, 2008). This in turn can alter entire ecosystem dynamics, as soil organisms play a foundational role in nutrient cycling. The loss of earthworms may also impact higher trophic levels, such as birds and mammals that rely on them as a food source. Moreover, the decline in microbial diversity associated with invasive species-induced soil changes can further disrupt soil stability, making it more prone to erosion and degradation. Besides, decreased earthworm activity can negatively impact plant growth, as reduced burrowing limits nutrient mixing and root penetration (Singh *et al.*, 2019; Liu *et al.*, 2020). These implications highlight the importance of understanding and mitigating the effects of invasive plants on soil macrofauna biodiversity. Understanding the mechanisms through which invasive plants influence earthworms can help develop conservation strategies that mitigate their negative effects. Hence, future studies may focus on identifying soil management practices that enhance earthworm resilience in invasive plant-affected habitats. Additionally, restoration

efforts may prioritize the removal of invasive plants and the reintroduction of native vegetation to support earthworm biodiversity.

Impacts of invasive plants on arthropod populations

Like annelids and earthworms, soil arthropods – such as ants, mites, springtails and beetles – play a vital role in ecosystem functioning through nutrient cycling, soil formation, decomposition, food web dynamics and soil aeration (Rousseau *et al.*, 2013; Sofo *et al.*, 2020). However, invasive plants can profoundly affect these ecosystem functional roles of soil arthropods (van Hengstum *et al.*, 2014). Invasive plants use various mechanisms to impact soil arthropods, for instance, changes in litter quality and quantity, alteration of soil chemistry, structure and microbial communities, and microhabitat modification (Bohlen *et al.*, 2004; Hale *et al.*, 2005; Hendrix *et al.*, 2008; Ibrahima *et al.*, 2017; Ojija and Manyanza, 2021). Often, invasive plants produce litter with different chemical and physical properties compared to native vegetation. This influences the composition of detritivores, arthropods that rely on organic matter for food and habitat (Wiatrowska *et al.*, 2024). Some invasive plants modify soil pH, nitrogen content and microbial activity, indirectly impacting soil arthropod populations that depend on specific soil conditions or microbe–arthropod interactions. Additionally, dense invasive plant cover may affect soil temperature, moisture and aeration, all of which are important for soil arthropod survival and activity (Herrera and Dudley, 2003; Ogura-Yamada and Krushelnycky, 2020; Wekhanya *et al.*, 2020).

Invasive plants can affect soil arthropod communities (i.e. abundance, diversity and composition) because they alter composition of native flora and fauna (Braschi *et al.*, 2021; Pearson *et al.*, 2024), disrupting soil nutrient cycles and trophic interactions (Ehrenfeld, 2010; Ojija, 2024). Also, by altering habitat complexity, food resource availability and microclimate conditions, invasive plants exert varying effects on arthropod taxa (van Hengstum *et al.*, 2014; Bobuřská *et al.*, 2025). Earlier studies have shown that an invasive plant *Lantana*

camara (Lantana) decreased Collembola and Acari diversity (Wekhanya *et al.*, 2020; Tlou and Duffy, 2022). *Mikania micrantha* (bitter vine) shifted Formicidae and Araneae composition (Ehrenfeld and Scott, 2001) and *Carpobrotus* species negatively affected spider assemblage dynamics (Braschi *et al.*, 2021).

Moreover, some invasive plants have been reported to change the physical environment by increasing soil organic matter due to rapid litter accumulation, altering soil pH and moisture levels, and modifying shading, which influences soil temperature and microbial communities (Ojija and Manyanza, 2021; Torres *et al.*, 2021). It was also reported that invasive plants can disrupt soil trophic interactions by reducing detritivore abundance, affecting decomposition rates, altering predator–prey relationships and changing herbivore populations (Aloo *et al.*, 2013; Shuvar *et al.*, 2021; Nunez-Mir and McCary, 2024). A study from East Africa on *L. camara* demonstrated its negative effects on soil arthropod communities by increasing soil organic matter, which altered microbial activity and shifted fungal-feeding arthropod populations (Sharma *et al.*, 2005; Wekhanya *et al.*, 2020; Tlou and Duffy, 2022).

Given these profound ecosystem-level changes, management strategies can focus on restoring native vegetation, implementing biological control (Banks-Leite *et al.*, 2020; Ojija *et al.*, 2024) and enhancing soil health through conservation agriculture (Huerta and van der Wal, 2012; Zulu *et al.*, 2022). Understanding these changes is critical for ecosystem conservation, and future research should integrate long-term monitoring and experimental approaches to assess arthropod responses in various ecosystems.

Case studies of invasive plant impacts on arthropod communities

A study by Flaherty *et al.* (2024) showed that *A. petiolata* invasion led to reduced abundance and diversity of Collembola and oribatid mites due to altered soil pH and microbial shifts. This is because the *A. petiolata* releases allelochemicals that disrupt mycorrhizal fungi and reduce the quality of leaf litter (Flaherty *et al.*, 2024). In riparian and urban ecosystems, *F. japonica* was

Table 10.4. Some examples of invasive plants and their impact on soil arthropod communities.

Invasive plant	Affected arthropod group	Change in abundance and diversity	Source
<i>Lantana camara</i>	Collembola, Acari	Decline in diversity	Wekhanya <i>et al.</i> (2020), Tlou and Duffy (2022)
<i>Eichhornia crassipes</i>	Coleoptera, Diptera	Increase in detritivores	Getahun and Kefale (2023)
<i>Mikania micrantha</i>	Araneae, Formicidae	Shift in species composition	Ehrenfeld and Scott (2001)
<i>Euphorbia esula</i> and <i>Cirsium arvense</i>	Ground-dwelling invertebrates (arthropods)	Decrease in abundance and species richness	Pritekel <i>et al.</i> (2006)
<i>Phytolacca americana</i>	Ground-dwelling forest arthropods (Carabidae and Formicidae)	Changes in species composition and abundance	Schirmel (2020)
<i>Arundo donax</i>	Ground-dwelling insects	Changes in habitat quality and vegetation structure in riparian systems	Herrera and Dudley (2003), Maceda-Veiga <i>et al.</i> (2016)
<i>Spiraea tomentosa</i>	Uropodina mites	Altered community composition	Wiatrowska <i>et al.</i> (2024)
<i>Frangula alnus</i>	Hemiptera, Diptera	Increase in abundance and diversity of certain arthropods	Greenleaf <i>et al.</i> (2023)
<i>Carpobrotus</i> spp.	Spiders	Changes in assemblage dynamics	Braschi <i>et al.</i> (2021)
<i>Asclepias syriaca</i>	Ground-dwelling arthropods (diplopods, spiders and ants)	Altered community structure and reduced diversity	Gallé <i>et al.</i> (2015)

reported to significantly change litter decomposition rates and soil microhabitats (Ehrenfeld and Scott, 2001; Ehrenfeld, 2010). Gerber *et al.* (2008) found a decrease in abundance and richness of soil macroarthropods, including Carabidae and Staphylinidae beetles, due to the low palatability and slow-decomposing litter of the invader. Furthermore, Herrera and Dudley (2003) reported significant reductions in soil arthropod abundance and diversity in areas invaded by *Arundo donax* (the giant reed), attributing these declines to the plant's dense canopy cover and alterations in litter decomposition (Table 10.4). Similarly, another study observed that arthropods in *A. donax*-invaded soils were smaller, and the absence of specific taxa within trophic guilds – or even entire trophic groups such as parasitoids – indicates that changes in the food web structure in these invaded areas are likely (Maceda-Veiga *et al.*, 2016).

Moreover, invasive *Spartina alterniflora* was reported to alter the soil structure and salinity in Chinese estuaries, thereby causing the decline in abundance and diversity of soil arthropods (Huang *et al.*, 2022). Huang *et al.* (2022) documented changes in soil macrofauna including declines in native detritivore and predator arthropods, attributed to reduced oxygen levels and altered soil pH in *S. alterniflora*-invaded habitats (Table 10.4). Additionally, modest but statistically non-significant increases in the abundance and species richness of forest floor-dwelling invertebrate communities, particularly arthropods, were reported following the suppression of the invasive species *Solenopsis papuana* (Ogura-Yamada and Krushelnycky, 2020). In addition, in East African wetlands, accumulation of decomposing *Eichhornia crassipes* (water hyacinth) was claimed to reduce oxygen availability and cause the soil to become

compacted (Table 10.4), leading to decreases in detritivorous arthropods like springtails and woodlice (Aloo *et al.*, 2013).

Despite the overall negative impact of invasive plants on soil arthropod communities, some studies highlight that not all invasive plants have adverse effects on these macrofauna (Srivastava *et al.*, 2014; Gallé *et al.*, 2015; Mantoani *et al.*, 2022; Getahun and Kefale, 2023). In fact, some invasive plants can promote or increase the abundance of certain arthropod groups (Srivastava *et al.*, 2014). For instance, it was reported that *E. crassipes* contributed to an increase in detritivore populations, particularly among groups such as Diptera and Coleoptera (Getahun and Kefale, 2023). This increase is likely driven by the enhanced availability of organic matter provided by the plant's decaying biomass, supporting higher detritivore abundance (Getahun and Kefale, 2023). Furthermore, Gallé *et al.* (2015) observed that the invasive plant *Asclepias syriaca* increased the abundance of ant species, likely due to indirect food web interactions where ants are attracted to aphids that inhabit the plant. Additionally, it was reported that *Gunnera tinctoria* (giant rhubarb), a nitrogen-fixing invasive plant, increased earthworm abundance and diversity in some ecosystems (Mantoani *et al.*, 2022).

Impacts of invasive plants on gastropod communities

Gastropods, including snails and slugs, play essential roles in ecosystems as decomposers and grazers, contributing to nutrient cycling and soil structure maintenance (Ovando *et al.*, 2019). Nevertheless, their populations can be significantly impacted by environmental changes (Strong *et al.*, 2008), particularly those induced by invasive plants. Invasive plants can alter habitat structure, microclimatic conditions and food availability, leading to shifts in gastropod communities (Ojija *et al.*, 2024). One of the primary ways invasive plant species impact gastropod communities is through habitat modification (Strong *et al.*, 2008; Ovando *et al.*, 2019). Many invasive plants alter the physical structure of ecosystems, affecting soil moisture, temperature

and leaf litter accumulation, all of which are critical for gastropod survival. Previous studies assert that dense stands of *Impatiens glandulifera* reduced ground-level light penetration and created humid microhabitats that may have favoured certain slug species while negatively affecting others that preferred drier conditions (Ruckli *et al.*, 2013; Kielytk and Delimat, 2019; Seeney *et al.*, 2019; Coakley and Petti, 2021). Similarly, it was asserted by Vacek *et al.* (2020) and Casati *et al.* (2023) that *Rhododendron ponticum*, an aggressive invader in European woodlands, altered leaf litter composition and reduced understorey plant diversity, leading to a decline in native gastropod populations.

Since gastropods rely heavily on leaf litter, fungi and decaying organic matter as their primary food sources, the introduction of invasive plants might affect their diet quality and availability (Sharma *et al.*, 2005; Ojija *et al.*, 2024). This is because invasive plants tend to alter the nutritional composition and decomposition rates of leaf litter. Previous studies have shown that the leaf litter of some invasive plants, such as *Ailanthus altissima* (tree of heaven), has a lower nutrient content and decomposes at a slower rate, reducing the availability of high-quality organic matter for gastropods (Schweizer *et al.*, 2019). Additionally, invasive grasses like *Microstegium vimineum* outcompete native plant species and produce litter with high silica content, which is less palatable to decomposer gastropods (Strickland *et al.*, 2011). Besides, invasive plants can indirectly impact gastropods by facilitating the spread of non-native gastropod competitors or predators (Watz and Nyqvist, 2022). For instance, invasive plants that create dense vegetation cover and abundant leaf litter may provide ideal habitats for invasive gastropods; one example is *Arion vulgaris* (Spanish slug), which has been shown to outcompete native species (Watz and Nyqvist, 2022). Furthermore, invasive plants that attract non-native predators, like *Platydemus manokwari* (predatory flatworms), can increase predation pressure on native gastropod populations, further threatening their survival (Doherty *et al.*, 2016).

Changes in microclimatic conditions due to invasive plants can further create physiological stress for gastropods. Invasive species like *L. camara* form thick, impenetrable thickets that alter soil moisture levels and

reduce temperature fluctuations, creating conditions that may not be suitable for native gastropods (Sharma *et al.*, 2005). In contrast, invasive grasses that dry out quickly can lead to desiccation stress in moisture-dependent gastropods, reducing their population densities in affected areas (Keller *et al.*, 2011). The decline of gastropod populations due to invasive plant impacts can have broader ecological consequences. Gastropods contribute to the breakdown of organic matter and facilitate nutrient cycling in forest and grassland ecosystems (Wronski and Hausdorf, 2010). A decline in gastropod diversity can lead to slower decomposition rates, altered microbial communities, and changes in soil structure (Vilà *et al.*, 2011; Zulu *et al.*, 2022). Furthermore, many gastropods serve as prey for birds, amphibians and small mammals, meaning their population declines can disrupt food webs and impact higher trophic levels (Dhiman *et al.*, 2020; Mohammadi and Ahmadzadeh, 2024).

In general, invasive plants exert significant effects on gastropod communities through habitat modification, changes in food availability, increased competition and predation, and shifts in microclimatic conditions. These impacts contribute significantly to population declines and biodiversity loss, with cascading effects on ecosystem functions such as nutrient cycling and decomposition (Dhiman *et al.*, 2020). Thus, future research may focus on long-term monitoring of gastropod responses to invasive plant management strategies, as well as conservation efforts aimed at preserving native plant communities to maintain gastropod diversity.

Strategies for protecting soil macrofauna populations from invasive plants

Effectively mitigating the impact of invasive plants on soil macrofauna – including earthworms, arthropods and gastropods – requires an integrated approach that combines ecological restoration, biological control, soil enhancement techniques and proactive monitoring (Moran *et al.*, 2005). These strategies help restore soil

conditions, promote soil macrofauna biodiversity and maintain overall ecosystem stability.

Restoration of native vegetation

Replacing invasive plants with native vegetation is a fundamental step in restoring soil ecosystems. Native plants contribute to soil health by supporting diverse soil macrofauna communities, including earthworms, arthropods and gastropods. They provide suitable microhabitats, increase organic matter input and restore natural nutrient cycling, creating a balanced environment for invertebrate populations. Invasive species removal should be conducted using environmentally friendly methods such as manual removal or targeted herbicide application to minimize harm to soil organisms. In cases where invasive plants have significantly altered soil conditions, gradual restoration strategies should be implemented to ensure the successful re-establishment of native vegetation without further disruption to soil biodiversity.

Biological control methods

Biological control offers a sustainable approach to managing invasive plant species without the use of chemical herbicides that could negatively affect soil invertebrates (Ojija and Ngimba, 2021; Ojija *et al.*, 2024). The introduction of natural enemies, such as herbivorous insects, fungal pathogens or grazing animals, can help reduce the spread and dominance of invasive plants (Gaskin *et al.*, 2021). This, in turn, benefits soil macrofauna by restoring habitat conditions (Moran *et al.*, 2005). For instance, introducing specialist insect herbivores has been effective in controlling invasive plants like *E. japonica* and *P. australis*, helping to improve soil structure and nutrient availability. However, biological control programmes must be carefully monitored to avoid unintended ecological consequences, such as the introduction of new invasive species or disruption of native arthropod populations.

Soil amendments and habitat restoration

Enhancing soil quality through the addition of organic matter can help counteract the negative

effects of invasive plants on soil macrofauna. The application of compost, mulch or biochar improves soil structure, increases moisture retention and promotes microbial activity, creating a more hospitable environment for earthworms, arthropods and gastropods. Organic soil amendments also enhance decomposition processes, restoring food availability for detritivores and decomposer organisms. Additionally, habitat restoration strategies like controlled grazing, conservation tillage and agroforestry practices can support soil macrofauna biodiversity by maintaining suitable habitats for soil invertebrates.

Early detection and rapid response

Monitoring soil communities in areas at risk of invasion is essential for detecting early changes in soil macrofauna populations and implementing timely interventions (Mgobozi *et al.*, 2008). Regular assessments of soil biodiversity, including earthworm abundance, arthropod diversity and gastropod distribution, can provide valuable insights into the effects of invasive plants on soil ecosystems. Rapid response strategies such as targeted invasive plant removal and habitat restoration can help prevent further degradation of soil macrofauna communities (Mgobozi *et al.*, 2008). Collaborative efforts between researchers, conservation practitioners and local communities can enhance monitoring efforts and facilitate early management actions before invasive plants establish dominance.

Integrated management approaches

A combination of restoration, biological control, soil amendments and monitoring is the most effective way to protect arthropod, earthworm and gastropod populations from invasive plants. Integrating these strategies into broader land management and conservation policies can help maintain soil macrofauna biodiversity and ecosystem resilience. Public awareness campaigns and stakeholder engagement in invasive species management can also promote

sustainable land-use practices that support soil health and macrofauna biodiversity conservation. As climate change and human activity continue to drive the spread of invasive plants, adaptive management strategies will be vital in safeguarding soil macrofauna populations and preserving soil ecosystems. Future research should focus on long-term monitoring of soil communities in invaded landscapes, evaluating the effectiveness of different management techniques and developing innovative solutions to restore soil biodiversity in affected areas.

Conclusion

The studies reviewed here consistently show that invasive plants can have substantial negative impacts on soil macrofauna communities – including arthropods, gastropods and annelids – by disrupting microhabitat conditions, altering litter quality and changing soil chemistry. These disruptions often reduce soil biodiversity, impair nutrient cycling and compromise overall ecosystem resilience. However, it is noteworthy that not all effects of invasive plants on soil macrofauna are negative. Some studies have demonstrated that certain invasive plants may actually enhance the abundance and diversity of soil macrofauna in particular ecosystems. This highlights the complex and context-dependent nature of invasive plant impacts on soil communities. Overall, it is essential to recognize that invasive plants can exert both positive and negative influences on local soil macrofauna assemblages. Future research should adopt a multi-trophic and long-term perspective, with particular emphasis on understudied ecosystems and taxonomic groups, to improve our understanding and inform effective management and restoration strategies. Importantly, a deeper understanding of how native soil macrofauna assemblages respond to these changes is vital for managing these novel ecosystems and maximizing their potential biodiversity benefits.

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