



# Soil Quality Indicators

## Earthworms

Earthworms are native to non-glaciated areas of North America, but non-native species from Europe and Asia also exist here. Earthworms are classified into three groups based on their habitat. Litter-dwellers live in the litter, ingest plant residues, and may be absent in plowed, litter-free soil. Mineral soil-dwellers live in topsoil that is rich in organic matter. They burrow narrow channels and feed on a mixture of soil and plant residues. Deep soil-burrowers (night crawlers) dig long, large burrows into deep soil layers. They carry with them plant residues for consumption. Earthworm cast is digested material that is excreted back into the soil. Cast is enriched with nutrients (N, P, K, and Ca) and microorganisms during its passage through the worm's digestive system. Fresh cast is a site of intense microbial activity and nutrient cycling. Earthworms contribute nutrients to the soil and improve porosity, tilth, and root development. They are measured in number/m<sup>2</sup>.

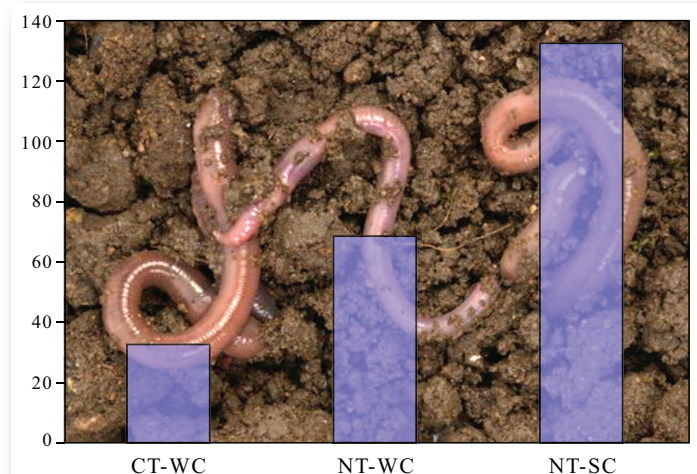
## Factors Affecting

**Inherent** - Earthworms are found in various environments, but seasonal and climactic variations affect their abundance, distribution, and activity. They are most active in the spring and autumn. Soil moisture, aeration, temperature, and texture affect earthworm populations. Water makes up more than 75% of the earthworm's body weight, so moist soils are preferred to prevent dehydration. Earthworms acclimate quickly by moving to humid sites or by entering a resting state. In the absence of mulch, very high or freezing soil temperatures can drastically reduce earthworm populations in a short time, but the lethal temperature is variable among species. A generalized range for earthworm activity is 32 – 86 degrees F. Stable aggregates contain organic matter and improve porosity, consequently improving air circulation, drainage and infiltration, which favor earthworm establishment.

Silty soils with high water holding capacity and organic matter provide ideal habitat for earthworms compared to sandy soils, which have lower organic matter content and water holding capacity, and dry and reach uncomfortable temperatures quickly. Deep soils are the favorite niche for earthworms, especially shallow soil-burrowers.

**Dynamic** - Earthworm abundance and activity trend with the amount and quality of plant residues, which provide food and mulch for habitat. Mulch helps maintain soil moisture and moderates soil microclimate, providing adequate time for earthworms to migrate and escape high or freezing temperatures. No-till and other conservation practices create ideal conditions for earthworms. The population in no-till fields can reach two to three times that in conventionally tilled fields (fig. 1). Populations of litter-dwellers and night crawlers may drop and even vanish in conventional tillage systems because of the destruction of burrows and depletion of surface residues. Earthworm populations are generally high and active in grassland due to the thick surface cover and continuous supply of food from residues and animal wastes.

While neutral pH is ideal, earthworms can adjust to pH 5–8 with some species tolerating even more acidic soils. Oxygen requirements also vary among species with some tolerating low amounts. Ammonia and ammonia-based fertilizers are toxic to earthworms due to acidic conditions created by their use. Herbicides tend to have low toxicity to earthworms if used at the recommended rate, especially when applied in bands. However, atrazine, which is widely used, is reported to be slightly toxic. Carbamate insecticides (table 1) and fungicides (carbendazim, benomyl) have severe adverse effects on earthworms.



*Figure 1. Effect of tillage and crop on earthworm number/m<sup>2</sup>. CT=conventional till, NT= no-till; W=wheat, C=corn, S=soybean. Adapted from Hubbard, et al. 1999.*

## Relationship to Soil Function

Despite some reservations, there is evidence that earthworms contribute to crop production. Earthworms play a key role in modifying the physical structure of soils by producing new aggregates and pores, which improves soil tilth, aeration, infiltration, and drainage. Earthworms produce binding agents responsible for the formation of water-stable macro-aggregates. They improve soil porosity by burrowing and mixing soil. As they feed, earthworms participate in plant residue decomposition, nutrient cycling, and redistribution of nutrients in the soil profile. Their casts, as well as dead or decaying earthworms, are a source of nutrients. These beneficial effects stimulate root growth and proliferation deep into the soil to satisfy nutrient and water requirements. Roots often follow earthworm burrows and uptake available nutrients associated with casts.

*Lumbricus terrestris*, or the night crawler, and other non-native earthworms have displaced many native species across the United States. In Northern forests, their populations can reach such high levels that no litter can be maintained on the forest floor.

## Problems with Poor Populations

Low or absent earthworm populations are an indicator of little or no organic residues in the soil and/or high soil temperature and low soil moisture that are stressful not only to earthworms, but also for sustainable crop production. Earthworms stimulate organic matter decomposition. Lack of earthworms may reduce nutrient cycling and availability for plant uptake. Additionally, natural drainage and aggregate stability can be reduced. Soil remediation to increase nutrient cycling, break up compacted layers to improve aeration and drainage, and stabilize soil to protect it from erosion may be needed. Some soils are naturally productive without earthworms because of their inherent properties.

## Improving Populations

No-till increases plant residues and improves soil structure, providing improved habitat for earthworms. Studies conducted in the Midwest showed that in no-till systems, the combination of soil moisture, temperature, and quality of food supply are essential factors for earthworm population growth. Legumes, alone or in rotation, seem to be preferred by earthworms because of the quality of food they provide (fig 1). Deep soil-burrowers are lacking in plowed fields and changing to no-till may not help their quick establishment unless they are introduced first. Seeding earthworms is a potential technique to reintroduce them, but it is not practical on a large scale. Compared to other ecosystems, agricultural soils are generally dominated by species adapted to disturbance, low organic

matter content, and a lack of surface litter, so the management practices listed below should increase earthworm populations. Sandy or wet heavy clay soils may not naturally harbor significant earthworm populations, but irrigation and drainage can help provide favorable conditions for earthworms to thrive. (In areas where restoration of native species is a goal, removal of exotic species is a must.)

The following practices boost earthworm populations:

- Tillage Management (no-till, strip till, ridge till)
- Crop Rotation (with legumes) and Cover Crops
- Manure & Organic By-product Application
- Pasture & Hayland Management
- Soil Reaction (pH) Management
- Irrigation or Drainage

## Measuring Earthworm Abundance

Earthworm populations are measured by counting the number of earthworms/m<sup>2</sup> as described in the Soil Quality Test Kit Guide, Section I, Chapter 10, p 22-23. See Section II, Chapter 9, p 73 - 75 for interpretation of results.

References:

Brady CN and RR Weil. 1996. *The Nature and Properties of Soils*. Prentice-Hall.

Edwards CA and CI Bohlen. 1996. *Biology and Ecology of Earthworms*. Chapman & Hall, NY.

Hubbard VC, et al. 1999. Earthworm response to rotation and tillage in Missouri claypan soil. *Biol Fertil Soils* 29:343-7.

## Specialized equipment, shortcuts, tips:

Use recommended products to bring deep-burrowing earthworms out at the soil surface. A count of 100 earthworms/m<sup>2</sup> in agricultural fields is considered good.

**Time needed:** 30 minutes

*Table 1. Insecticides harmful to earthworms*

Insecticide	
Common Name	Trade Name
Aldicarb	Temik
Carbaryl	Sevin
Carbofuran	Furadan
Clorpirifos	Dursban
Methomyl	Lannate