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Using Soil Fauna to Improve Soil Health

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Introduction

Soil fauna communities, including soil inhabiting invertebrates, are known to improve soil structure by decreasing bulk density, increasing soil pore space, soil horizon mixing, increased aeration and drainage, increased water holding capacity, litter decomposition and improving soil aggregate structure (Abbott, 1989). In healthy soils invertebrates are abundant. With adequate food supply and habitat requirements, soil fauna populations will thrive with minimal maintenance. For an area with degraded soils, such as mined or intensely cultivated sites, the reestablishment of invertebrates can be simply a matter of removing the cause of degradation, or may involve more extensive site preparation techniques and reintroduction methods. There are three categories of invertebrates that live in the soil. They consist of micro-fauna, Protozoa and Nematoda, meso-fauna, which include mites and Diptera (fly) larvae, and macro-fauna, which include termites (*Mecrotermes*) and earthworms (Abbott, 1989).

Due to the large number of types of invertebrates involved in the soil health, this paper will be limited to protozoan, nematodes, termites and earthworms. The paper will describe the fauna's primary habitat, their role in soil health and ways to promote fauna colonization.

Soil Fauna Communities And Their Function In Soil Health

Protozoan and nematodes are found predominately in arid soils, consisting of a primarily sandy, dry structure. They inhabit the soil water particles. Protozoan are able to go from an inactive, dormant state, when conditions are unfavorable, such as when soil water levels are low, to an active state when more water is available (Whitford et al. 1995). Nematodes are parasitic and feed on plants. Studies have shown parasitism at low levels causes an increase in nitrogen mineralization by plants (Stork and Eggleton, 1992). Micro-fauna enhance the decomposition of plant material by breaking down and fragmenting ingested litter with an enzyme cellulase in their gut. The fragmented litter is then available for other microbes to decompose (Abbott, 1989).

Termites, *Mecrotermes*, are found in open savannas, tropical and subtropical areas with semi-arid to arid soils. Some species include *Hospitalitermes*, found in the rainforests of Borneo and *Cubitermes glebae*, found in the forests of west Africa (Eggleton, 1996). Termites build mounds of soil above ground and burrow into the soil to create extensive tunnels called galleries. Burrowing moves soil and litter, thus changing the soil texture, and increasing soil porosity and water infiltration (Curry and Good, 1992; Stork and Eggleton, 1992). Termites consume a large amount of animal dung and litter. The consumption of animal dung is especially important to soil and plant health due to the dung's slow rate of decomposition. Removing the dung, which can prevent plant growth, is essential for the ecosystem's productivity (Whitford et al. 1995). Digesting the dung makes nutrients readily available to the plants from the termites wastes.

Earthworms are abundant in temperate, mesic mineral soils as well as humid tropical soils (Curry and Good, 1992). There are three types of worms as described by Kladivko (1997): litter-dwellers, shallow soil dwellers and the deep-burrowers. The litter-dwelling species, such as *Dendrobaena octaedra,* reside in the litter layer of forests. The shallow-dwelling species, including *Lumbricus rubellus,* live primarily in the upper 12 inches of soil. They have no permanent burrows, but rather travel throughout the topsoil. The deep-burrowing worms are the nightcrawlers, such as *Lumbricus terrestris* These worms have permanent burrows that can reach five to six feet deep.

Earthworms play a large role in the health of soil and plant productivity. Their burrowing in the soil creates channels for aeration, root penetration and water infiltration (Curry and Good, 1992). Plant roots are able to penetrate into the soil easier with gaps in the soil. Worms burrow through the soil and ingest soil and plant residues. *L. terrestris* pulls plant material from the soil surface down into their burrows for eating at a later time (Kladviko, 1997) Worms excrete a material called castings, or casts, which is a mixture of soil and partially digested plants. These casts have nutrients readily available for plants and "work like time-released fertilizer…" by providing nutrients easily absorbed by plants (Lake and Supak, 1996). Studies have shown that earthworm inoculation in poor soils leads to increases in plant yields (Edwards and Bater, 1992).

Promoting Soil Biota Colonization

Providing a vegetative cover, to serve as a basic food source for soil biota and carbon source for plants, is an essential step in aiding soil invertebrate colonization (Abbott, 1989). With vegetative plant cover and appropriate habitats, including logs and adequate moisture, soil biota are able to colonize. However, these are not always available and the site may need transplanted organisms. The amount of intervention in soil fauna reestablishment depends on the level of degradation of the soil. For intensively cropped areas, reestablishment of species will accelerate once the land is taken out of cultivation. Soil fauna thrive with conditions that have minimal inputs of fertilizers and pesticides. For areas that will continue to be cultivated, changing to a no-till system and leaving adequate amounts of residue on the topsoil will help encourage healthy populations of soil fauna (Curry and Good, 1992). Earthworms have been shown to naturally colonize in the following order: surface dwelling species, shallow burrowing species (within 3-5 years) and eventually deep burrowing species (up to 5-10 years). Another consideration that needs to be addressed is the size of the area. Some invertebrate species have limited dispersal capabilities and cannot reestablish in a large area with out inoculation. For example, some earthworms can travel at a rate of 0.4 meters per year, making natural recolonization take up to ten years (Ma and Eijackers, 1989).

For areas with extremely degraded soils, such as mined sites, limiting factors such as a low pH, high salinity, presence of metal ions or lack of food base can inhibit soil biota colonization (Ma and Eijsackers, 1989). Adding lime to the soil will help neutralize acidic soils (Abbott, 1989). The existence of fly ash from coal increases soil salinity to a level toxic for earthworms, but can be eliminated through natural weathering within two to three years (Curry and Good, 1992). Soil that is removed from mined sites is frequently stockpiled to be returned to the site after completion of the mining. The use of stockpiled soil can help, but this would depend on the amount of time the soil has been stockpiled. A study has shown the fauna do not live much longer than a few months in stockpiled soils (Viert, 1989).

Resoiling to encourage colonization can be carried out by mechanically mixing fresh soil from an adjacent site and litter with habitat appropriate fauna (Curry and Good, 1992). Earthworm introductions can be ameliorated with a good surface layer of vegetative litter or mulch. Small grass sods with earthworm populations can then be planted directly onto the soil surface to introduce earthworms. Studies have shown the use of sods is not successful with deep burrowing species such as *Lumbricus terrestris* (Curry and Good, 1992).

For other small scale introductions, Lake and Supak (1996) suggest creating one's own worm habitat, involving the use of grass clippings and other mulch, and digging a hole and burying the mulch in the ground. The mulch provides necessary habitat and food sources needed for the worms. The use of buried mulch slows down the rate of soil drying in the fall and winter, leaving adequate moisture for the worms (Kladviko, 1997). Worms are available for sale through the International Worm Growers Association.

Specific introductions of termites have not been studied in much detail and are not considered hopeful, but incorporating surface plant residues into the soil can foster termite activity (Curry and Good, 1992).

Case Evaluation

Restoration of soils and soil fauna requires proper planning and evaluation. Reclamation projects require a knowledge of what species were present before alteration and a goal for restoration. Having a knowledge of what species can be supported in an area is essential (Viert, 1989). In cases of mined lands, creating designs and developing criteria for implementing these designs should be established before the mining has occurred. These plans can give an idea as to the amount of money will be necessary for an appropriate restoration effort. Once the restoration is completed, evaluating and changing methods will help other projects.

A study by Dunger (1989) examined three areas in Germany that had been coal mined for various amounts of time. The three areas were: Gorlitz, Leipzig, and Niederlausitz. The regions varied by size and soil type, with the Gorlitz area narrower than the others (0.5Km) and therefore more favorable for natural colonization by earthworms. The Leipzig and Niederlausitz regions consisted of sandy or gravel soils with high levels of sulfides, making them acidic and have low moisture holding capacities.

The amount of site preparation necessary in the soils varied by area. All areas required liming to reduce acidity. The pH was brought to a tolerable level between 4-5 to the depth of 30-40cm. Afforestation with deciduous trees such as *Alnus glutinos* (Alder) and *Robinia pseudoacaccia* (Black Locust) in the Gorlitz region precluded the seeding of *Melilotus officinalis* (yellow sweet clover) and *Lupinus poltphyllus* (perennial lupin). The Leipzig region required the application of large amounts of Ca, P and K to the top 60cm of the soil.

The study showed earthworms were most successful when introduced with a technique of spacing out 100m grids of soil and incorporating food and worms into the plots. The above study found *Allobophora calignosa* more tolerant than other species of earthworms. This species is usually the first to colonize an area. *A. caliginosa* was able to create a dormant stage to accommodate the dry periods and tolerate lower pH levels. Within three to four years after the reclamation projects began, adequate vegetative cover and litter layer occupied the area and other species such as *Dendrobaena octaedra* established. In some areas, *L. terrestris* colonized after 20 years.

Limiting factors in the establishment of the earthworm populations were examined in this research study. Some populations will not disperse to deep levels due to remnant toxic soils, such as those with low pH. The depth of soil treatments, such as liming, does not reach some of the worms' habitat. The general lack of organic material as a food source for the worms limits the numbers of worms the soil can sustain.

A plot study of bauxite mined sites in Australia by Nichols, Wykes and Majer (1989) focused on different types of ground cover and the success of ant and termite colonization. Ant populations were found to be an indicator species as to the richness of other soil invertebrates. The study consisted of a plot, 10-20 hectares, which was not vegetated, one which was planted with *Eucalyptus calophylla* (marri) and the third had a native plant mix seeded. The results showed the seeded plot was colonized within three years, with diverse soil biota communities. The termite populations established and succeeded throughout the study period to include not only wood eating species, but also litter and grass eating species. The other two plots had relatively few species. This was due to the lack of litter cover and logs.

Conclusion

Having healthy soil fauna populations is beneficial to the soil. Developing a restoration project requires analysis of the resource to determine the level of degradation and amounts of site preparation necessary for reclamation. The literature examined did not have extensive information on pre-degradation site conditions, including the species of invertebrates present and ground cover. Having this information could give planners an indication of abundance and diversity of species adjacent to the site. These species have the potential of dispersing to the site.

Restoration projects require follow up evaluations to determine the success of colonization. Documentation of successes and failures can help future restoration projects succeed. Changes can be made to accommodate site preparation techniques overlooked or insufficient.

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