Chapter Seven

Soil Health Principles and Practices

What is the Basis for Soil Health Principles?

To answer this question, we need to go back to the main points made in Chapter Six: the soil is alive, the source of that life are the organisms in the soil ecosystem (the soil food web), and living organisms have certain basic needs. Those needs are energy, habitat, and diversity. When these needs are met, the life in the soil organizes stable, productive communities that are enormously beneficial to both the underground and above ground communities.

The soil health principles discussed in this chapter all derive from those basic needs, and from the overall intent of protecting and enhancing the life in soils. They also take into account the reality of ecological succession and its on-going impact on soils and crops.

The first four principles were developed by the Natural Resources Conservation Service (NRCS), a branch of the United States Department of Agriculture. The principles that follow the first four are derived from the growing body of soil-health literature, both scientific and practical.

Minimize Soil Disturbance

Soybeans grown into corn stalks in a no-till field in Union County, Iowa *(Figure 45)*
Source: USDA

This refers primarily to the practice of tillage (see **Figure 45**). Once we begin to see the soil ecosystem as an intricately structured community, the destructiveness of tillage becomes very apparent. Imagine how difficult life would be for you if every year somebody came around with a wrecking ball and destroyed your house. Most of your energy and money would be going into rebuilding each year and you would have little left for anything else.

Tillage is like that in its effects on soil, but of course it is a bit more than that, too. Farmers till for a reason – it has a powerful short-term effect. Tillage releases nutrients by introducing a big burst of oxygen into the soil, which stimulates the decomposer microbes. As these microbes explode in number, the predator microbes also increase, resulting in a flush of nutrients as the predator-prey action described in Chapter Three increases enormously in the rhizosphere. The soil is also loosened by tillage, allowing for easier planting, and weeds are uprooted and destroyed. All of these short-term benefits, however, come at a huge cost to the community below ground, and that eventually translates into greater costs to the farmer and to the environment.

Eliminating tillage has a number of challenges, dealing with which are beyond the scope of this primer. Nevertheless, we can say here that any practice that minimizes disturbance of the soil is good for the health of the soil. Both science and practical experience tell us that when the soil community is protected from violent and/or frequent disturbance, beneficial soil functions of all kinds gradually increase, so that the short-term fertility benefits of tillage are replaced by long-term, sustainable levels of fertility that at least match, and can often exceed, those of tillage. Of course, best results are obtained if all of the other soil-health principles are followed, as well. Reducing tillage, all by itself, may not protect, feed, and diversify the soil food web enough to compensate for the loss of tillage's short-term benefits.

Finally, we should note that minimizing soil disturbance allows ecological succession to proceed below ground. As discussed in Chapter Six, below-ground communities change with succession, just as above ground communities do. Tillage is a catastrophic event that knocks succession backwards, causing it to re-set. Not only does this encourage weeds, which are by definition pioneer species, but it also damages fungal hyphae, forcing these organisms to spend too much energy trying to rebuild their networks. This scenario frustrates the development of more established fungal communities, resulting in permanently bacterial-dominated fields. The long-term, sustainable benefits of a thriving, well-balanced soil food web require a more balanced ratio of fungus to bacteria, something that soils simply can't develop under a heavy tillage regime.

Keep the Soil Covered

There are two basic ways for farmers to keep the soil covered: with crop residues, and with cover crops. The basic benefit of covered soil is protection of the soil food web habitat. Both residues and living plant material protect the soil from temperature extremes, reduce the impacts of heavy rains and wind, and conserve moisture. All of these things directly benefit the members of the soil community. Covered soil is also more compatible with conditions found in ecosystems that are more advanced in ecological succession, as opposed to the more disturbed habitats of early succession, where soil is often bare and conditions are more extreme. The less harsh conditions under covered soil allow more advanced and productive soil ecosystems to form and sustain themselves.

Keep Live Roots in the Ground

To put it as plainly as possible, allowing soil to lie bare of living plant life *starves the organisms of the soil food web*. As discussed in Chapter Six, living soils require a consistent source of energy. Some of that energy comes from plant residues (another reason for the previous principle of keeping soils covered), but much of the energy in living ecosystems comes from plant root exudates, which of course requires that there be plants growing in the soil.

Starving the food web organisms has some very important negative consequences. Deprived of food, the microbes will either die or become dormant, depriving the communities (above and below) of their valuable services. But that, unfortunately, is not the whole story. Before the microbes go dormant or die, they will try to find energy in other places. The glues that hold soil aggregates together are not the preferred food of soil microbes (that really would not make any sense ecologically), but they will consume these glues if they have no other option. Of course, that is not good for your soil structure, and starving your microbes in this way on a consistent basis is a good way to ensure that your soil is structure-less and compacted.

It gets even worse than this. Mycorrhizal fungi are, as we discussed in Chapters Two to Four, fundamental to soil structure, natural fertility, disease suppression, and a number of other important soil functions. They are also what is called obligate symbiotes. What this means is that they don't have a choice with respect to their symbiotic relationship with plant roots; they need roots as hosts or they

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die. Accordingly, a bare field for months on end will mean low mycorrhizal numbers in your fields, with all that entails. Mycorrhizal spores will survive, of course, but instead of starting the new growing season with a full mycorrhizal network in place, you will be counting on those spores to repopulate the field, a slow and very energy intensive process from the fungal perspective. This is not efficient and over time a field can become a mycorrhizal desert, to the detriment of the soil ecosystem, plant yield and health, and the farmer's bottom line.

Maximize Diversity

Farmers can maximize diversity in any number of ways, including (but not limited to): more complex crop rotations; multi-species cover crop mixes (see **Figure 47**); a variety of inputs, such as various types of fertilizers, manures, composts, digestates, etc.; above-ground areas of pollinator habitat; and the use of different seed varieties. All of these tools help to ensure that the soil food web experiences a variety of inputs. For instance, using a mix of cover crops can provide a range of different plant root exudates, as different plants secrete different organic substances. It can also ensure that these exudates occur at different depths, as the various cover crops should have different root forms and lengths. Crop rotations can also provide these benefits and both rotations and covers can be used to simulate some degree of ecological succession, allowing the soil ecosystem to further develop its complexity, resilience, and productivity.

Multi-species Cover Crop *(Figure 46)*
Photo Credit: Stefan Zehetner, Huron County, ON

The above-ground diversity of plants also helps to ensure an above-ground diversity of animal life, particularly beneficial insects. The vast majority of insects are either beneficial to farmers or neutral. Therefore, the larger numbers of diverse species, the less chance that a pest will take over the empty niche that many farm fields become, from an ecological perspective.

When diversity rules, resilience is not far behind. When we look at how much redundancy exists in terms of functions in a good soil, it can be amazing. For instance, there may be hundreds or even thousands of species that perform the same task, such as secreting glues that bind mineral particles to make micro-aggregates, when it would seem that simply a high number of one or two varieties would suffice. However, when environmental conditions change, as they do all the time, it is good to have another set of organisms ready to take over when the first set can no longer manage the task. The soil dries out, for instance; this is no problem if you have a set of drought resistant microbes ready to step in and take over! The temperature climbs and your disease suppressors can't take the heat and go dormant? Again, no problem if the soil contains another set, perhaps sleeping up until now, who really like the heat and can't wait to swing into action.

Promoting diversity in all its forms builds and support resilient soil ecosystems. Resilience is important in any environment, but even more so when the climate is changing, becoming less consistent and predictable and prone to extreme events.

Some Other Important Soil Health Practices

Manage Nutrients Carefully

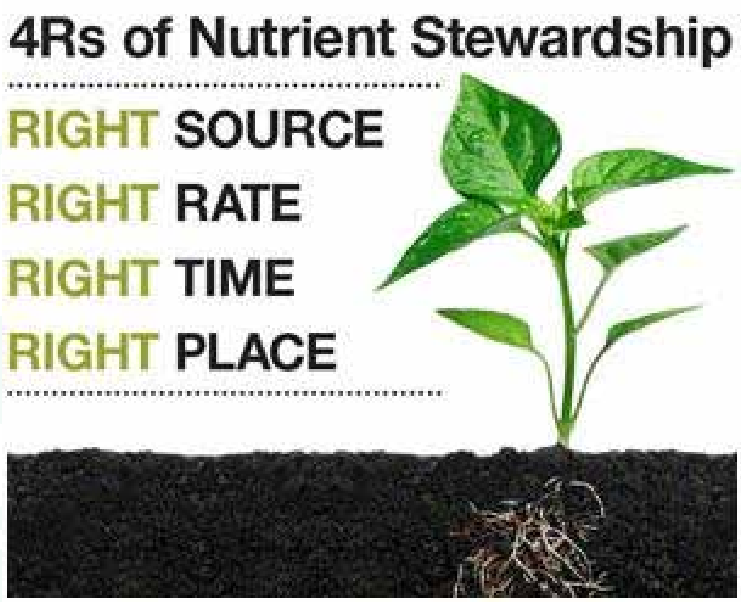
Nutrients of all kinds, organic or synthetic, are important and necessary. A farmer will not get a good crop without adequate nutrients. However, the ways in which nutrients are applied, in terms of amounts, timing, placement, etc., are also important. Too much nutrient, broadly applied, in combination with other factors, such as tillage and uncovered soil, can mimic an early successional ecosystem. It is similar to the results of a catastrophic event, such as flooding, fire or a major disease outbreak. Weeds are pioneer species, adapted to just such scenarios. It is not surprising, therefore, that bare soils, high in available nutrient, can experience very high weed pressure. In addition, some studies have shown that high levels of available P, and sometimes N as well (or in combination) suppress mycorrhizal fungi, diminishing this important source of natural fertility. Finally, excess nutrient levels often lead to run-off and pollution, which are costly both to the farmer and the environment.

The goal of a soil-health-inspired nutrient management plan should be to get the most out of natural fertility and, as much as possible, use synthetic fertility to complement and enhance, rather than replace, the natural system. Of course, finding the right balance is easier said than done, and we still have a lot to learn in order to be able to do this optimally. However, following the *4Rs program for nutrient use* (right source, right rate, right time, right place) is a very good place to start (see **Figure 47**).

Manage Crop Protection Products Carefully

As with nutrients, pesticides can be a double-edged sword. If not used carefully, or if over-used, they can negatively impact soil health in a variety of ways. Most of them do not discriminate between the "good guys" and the "bad guys" in terms of organisms; everything takes a hit. As with over use of nutrients, ecosystems may experience this as a type of disruption event, triggering secondary succession. For instance, when a field is chemically "burned down", this process destroys the competition and releases nutrients, mimicking a natural successional setback. Similarly, when fungicides are used too often, the beneficial fungi are constantly knocked back, and the field tends to become bacterial. Both of these examples result in a more simplified ecology similar to early successional scenarios, with all of the resulting issues for farmers.

This is not to say that farmers should never use any pesticides; rather, it is to point out that they should be used carefully and, in most cases, as a later line of defense, only after damage thresholds have been reached, as in the *Integrated Pest Management (IPM)* approach (see **Figure 48**). Pesticides in general can often be precluded through the use of other management techniques, but



4Rs of Nutrient Stewardship *(Figure 47)*

where they are used, it would only make sense to ensure that their impact on soil health is minimal by making them part of a broader management plan that includes a wide variety of practices based in all of the soil health principles described above. This will give the soil organisms the best chance to handle the chemical inputs without reducing the level of their functions.

Recent research by A&L labs, here in Ontario, has shown that the soil microbial communities are in general very resilient and can handle most pesticides (that is, break them down into harmless components), if the latter are used carefully and properly. This is good news, but should be taken in context. There is always a cost when chemicals are used: that cost can be light, and easily manageable by the soil food web; or it can be heavy, as when mycorrhiza have to expend energy that could be helping your plants to regrow hyphal networks destroyed as collateral damage of fungicide

OMAFRA IPM Training Manual *(Figure 48)*
Source: OMAFRA

use. Awareness of the costs and benefits by the farmer would seem to be the key.

Apply Organic Amendments such as Manure and Compost

Adding organic materials to soils is always good, for these substances both feed the soil food web and provide good habitat for its members. Compost, in particular, has another advantage – as an inoculant. What has traditionally been perceived as a disadvantage for organic inputs – their relatively low nutrient levels, as compared to synthetic fertilizers, can be seen, when looked at in a soil-health perspective, rather as a complement to chemical fertilization. This is because organic inputs can support the soil food web in ways that synthetic inputs cannot. Of course, these attributes often do

Beneficial Effect of Compost on Carrots
(Figure 49)
Photo Credit: Glenn Munroe

not carry the economic weight that the provision of nutrients do, but as we have seen in the previous chapters, this may not be an accurate assessment.

The research and resulting tools required to make a better economic analysis of the value of inputs such as compost are not yet complete and available for farmers to use. In addition, the need to mitigate and adapt to climate change may yet make additional revenues for using these materials a reality. However, even now, and just from a soil health

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