Chapter Eight
The Unique Role of Compost in Soil Health and Climate Change

"Compost returns organic matter to the soil and helps retain nutrients, improves water-holding capacity, improves soil structure, and reduces soil compaction caused by farm equipment."

- ***Agriculture and Agri-Food Canada***

Introduction: The Acknowledged Benefits of Compost

Adding compost to soil produces many benefits including (but not limited to):

- increased levels of soil organic matter (SOM);
- higher levels of natural fertility in soils;
- a stronger, healthier plant (see **Figure 49**);
- improved soil structure, which in turn leads to –
    - better water-holding capacity,
    - greater infiltration of rainfall,
    - reduced soil erosion,
    - less run-off of nutrients and other inputs, and
    - disease suppression.

Figure 49: Impact of Compost Application on a Carrot Crop
Photo Credit: Glenn Munroe

Controlled field trials with compost have shown generally positive results, with farmers finding slight to moderate yield increases, improved soil structure, and some disease suppression. The issue, however, has never been whether or not the compost provides benefits; rather, it has been whether or not the sometimes-inconsistent benefits were worth the additional cost.

This practical cost-benefit assessment, however, may require an update. A number of factors may be changing the assumptions underlying this issue, and we will look at each of them in some detail in this Chapter. In overview, they are:

- the rise in awareness of the importance of soil health;
- the increasing need to do something significant with respect to climate change;
- an evolving understanding of the co-benefits of compost use, and in particular, its potential ability to protect our fresh water supplies;
- the emergence of the concept of compost as an inoculant, whereby the cost-efficiency of compost use is given a substantial boost.

Scientific research has been the main driver in all of the above factors. In particular, the huge advances in genomic (DNA-based) analysis in the last decade are helping us to better understand what is going on in the soil. In turn, this better understanding is providing us with some powerful tools. Going forward, we should increasingly be able to:

- make our agricultural soils produce more, with fewer inputs;
- tackle climate change effectively and affordably;
- better protect our overall environment without sacrificing the economy; and,
- create the business opportunities and well-paying jobs of the future.

Compost can and should be a big part of all this. Let's take a close look at some of this new knowledge and the potential compost-related opportunities arising from it.

Compost and Soil Health

"Many organic materials serve both as fertilizers and soil conditioners: they feed the soil and the plants…..Soluble chemical fertilizers contain mineral salts that plant roots can absorb quickly. However, they do not provide a food source for soil microorganisms and earthworms. Over time, soils treated only with synthetic chemical fertilizers lose organic matter and the living organisms that help to build a quality soil."

- ***Food and Agriculture Association of the United Nations***

Compost's Versatility

Compost can be seen as the "swiss army knife" of soil health tools and practices. Why? Primarily because of its versatility.

Compost can be used to:

- enhance the benefits provided by other practices, such as cover crops;
- ameliorate the effects of less-than-ideal practices, such as tillage;
- build healthy soils; and
- help maintain that health.

Compost makes a very good partner with synthetic fertilizer, for at least two important reasons:

First, soil organisms are stimulated by the addition of nutrients, and they look to carbon for energy. Without plentiful carbon to feed these hungry microbes, SOM levels may decline. Compost supplies SOM.

Second, adding compost with fertilizer can increase the latter's efficiency. Compost increases the size of the soil food web. Any excess nutrients will be taken up by these organisms, preventing their loss via leaching.

And here is the key point: compost has a particular benefit that the other practices just don't have -- it can rapidly increase both the number and the diversity of a soil's food web. Well made, mature compost usually contains a greater concentration and variety of soil organisms than the soil that receives it. Of course, this depends on factors such as the source materials, where it was made, the composting methods used, etc., but good, mature compost is loaded with a wide variety of beneficial soil microbes. In fact, you could say that diversity is compost's forte.

We discussed earlier in this document how soil health influences fertility (Chapter Two), soil structure (Chapter Three), and disease and pest suppression (Chapter Four). Below are a few more details with respect to compost's potential role in each of these areas of concern to farmers.

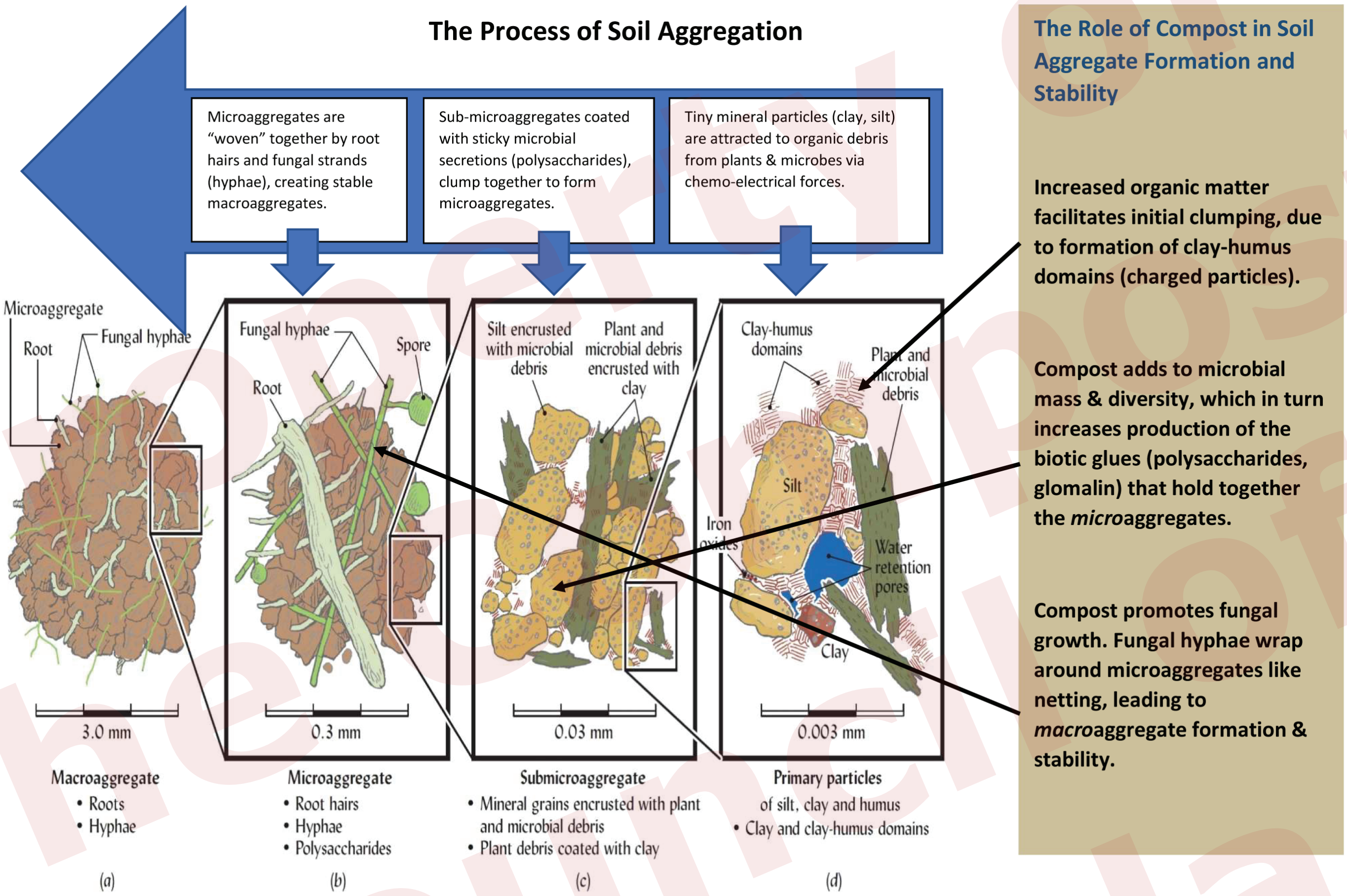
Soil Fertility

Compost hides its potency behind low NPK numbers. To understand what compost can really do, we have to look more closely at natural systems. As described in Chapter Two, natural soil fertility is not based solely on the amount of nutrient available to plants at any given time; rather, it is an ongoing product of a well-functioning soil food web. Plants depend on carbon-trading system elements such as the activities of microbes in the root zone (see discussion of the microbial loop, pp. 23-24) as well as mycorrhizal associations (pp. 24-25) to ensure that they get the nutrients they need, when they need them. Compost not only supports the creatures of the soil food web with food energy, nutrients, and habitat, but also adds diversity, making the systems referenced above more robust and reliable.

Soil Structure

The only real long-term solution to compacted soils is to build good soil structure. To do this, you must nurture and protect the soil organisms that create and sustain soil aggregates. This was discussed in detail in Chapter Three. **Figure 50** summarizes that discussion and adds some information on the potential role of compost in this process. In essence, compost supports the organisms that do the aggregating, and in particular the fungi.

Figure 50: Compost's Role in Soil Aggregation



[Image Credit: Original Diagram from *Weil, R.R., and N.C. Brady. 2017. The nature and properties of soils. 15th ed. Pearson, Columbus. 1086 p.*; further explanation of process (blue arrow) and notes on role of compost (sidebar) added by Compost Council of Canada.]

Why is this so important? Well, the latest science indicates that it is difficult, if not impossible, to have good, stable soil aggregates without having a good, stable population of beneficial soil fungi. The fungal filaments provide the necessary glues and "netting" to build the larger aggregates and to hold them together.

Mature compost both supplies and feeds soil fungi. Testing has revealed that compost piles, when left to mature, gradually become more fungal; that is, the biomass ratio of fungi to bacteria rises. This is due to the fact that fungi are better able than bacteria to break down the more complex, recalcitrant molecules that are left after the first flush of bacterial decomposition takes out all the "easy" stuff. Accordingly, the application of mature compost inoculates soil with various types of saprophytic fungi and then supports the growth of both saprophytic and mycorrhizal species, increasing the number and degree of the ecosystem benefits for which these organisms are largely responsible.

Disease Suppression

As mentioned above, quite a few studies have documented the disease-suppressive nature of compost. The exact mechanisms that are responsible for the suppression, however, are not well known. What we do know is that compost boosts the soil food web, both in terms of food supply and diversity. Therefore, in terms of disease suppression, it is likely that the soil organisms do the real work.

What kind of work? In Chapter Four, we set out the basic mechanisms in general terms:

- competition (beneficial microbes out-compete harmful ones);
- physical protection (microbes provide a physical barrier around plant);
- antagonism (e.g., production of antibiotics);
- direct consumption of pathogens by beneficial microbe predators;
- partnerships (microbes provide some type of chemical assistance to plant immune system);
- and, communications (plants receive advance warnings via the soil food web).

The potency of compost as a disease suppressant will depend to a large extent on the number and variety of its microbial populations. Some types of organisms in the compost might excel at surrounding roots and protecting them through sheer numbers; others (and we know these types exist) might produce antibiotics to fight off pathogens; while still others, such as the B. subtillis in Chapter Four, might specialize in helping plants activate their own defense mechanisms. A diverse, mature compost will likely include all of these groups.

Compost and Climate Change

You may already be aware that the composting process itself helps to reduce climate change. This is because composting diverts organic wastes from landfills. In landfills, organic residuals degrade anaerobically (in the absence of oxygen), resulting in the production of methane gas (see box on right, below).

It is certainly true that the composting process itself releases some greenhouse gases (GHGs). The main one is carbon dioxide (CO_2). But this gas would have been released as part of the normal carbon cycle; therefore, its release in the composting process adds no new GHGs to the atmosphere. However, some methane and nitrous oxide (N_2O) are also produced and these gasses are considered to be GHGs. Fortunately, in a well-managed composting system, very few of these gasses are emitted. In fact, the overall carbon footprint of composting is so good that some compost facilities are able to earn carbon offsets, just by doing their day-to-day business.

Reducing emissions of GHGs is crucial in fighting climate change but it is not the only way to go about it. Actually pulling carbon out of the atmosphere is also very important. In Chapter Five, we looked at how carbon gets sequestered in soils. The Marin Carbon Project shows that one application of compost to rangelands set up a feedback loop in the soil that resulted in a gain of about **one tonne of carbon per hectare per year for the full three years of the study** (and is projected to keep adding C for at least 10 years!!).

The Hidden Danger of Methane

Methane (CH_4) is generally stated to be about 20-30 times more potent than CO_2 as a greenhouse gas (GHG). However, that number provides only part of the story. GHG potency is generally measured over a 100-year timeframe. Unlike CO_2, methane doesn't last that long in the atmosphere, so measuring its impact over 100 years dilutes its potency. It is much more dangerous over the 20 years that it does hang around -- **84 times more potent than CO_2.** Why is this important? Well, to start with, most climate scientists believe that we have less than 20 years to get our GHG emissions under control if we want to avoid runaway climate change. Given that very short window, reducing methane emissions can be seen to be particularly important.

One of the main reasons that a single compost application was able to sequester so much carbon, for such a long time, is that it was applied to rangelands, rather than croplands. It is important to understand that on these particular lands:

- no tillage was happening;
- the ground was covered year-round;
- the ground cover included a wide diversity of plants; and,
- these plants also ensured that live roots were in the ground all year long.

Note that the above points are exactly the same as the basic soil-health principles described in Chapter Seven!

Does this mean that the added compost is not responsible for that large increase in soil carbon? No - as the increases occurred only on the soil where the compost was added.

The added compost was able to sequester so much carbon because there were no management practices working against it. The addition of compost to soils can result in high levels of carbon sequestration, given that the other main tenets of soil health are followed. This is an important point for farmers to keep in mind. It is almost certainly true that compost can build soil carbon much faster when used in conjunction with the other soil-health BMPs.

Does this mean that farmers who are not employing other soil-health BMPs should not bother to use compost? The answer is no – because compost can help your soil under any circumstances. It simply means that to experience compost's full value, you will need to make it part of a full soil-health based system (see Box on right).

Why not try this on a few acres?

See for yourself if the combination of compost with the other four soil-health BMPs (see Chapter Seven) can transform the health of your soils and boost their productivity. For more information on this approach, which people are calling "regenerative agriculture", visit the website of California State University, Chico, at

https://www.csuchico.edu/regenerativeagriculture/index.shtml

Compost and Fresh Water

General Benefits

Mature compost protects fresh water in a number of ways. As described above, when applied to agricultural land or turf, compost:

- improves soil structure, resisting compaction and allowing better infiltration of rainfall and increased water-holding capacity;
- reduces surface run-off of rain or irrigation water, protecting surface waters from many sources of pollution and reducing flooding;
- increases the number and variety of beneficial soil microbes, which break down toxic residues and clean water passing through the soil on its way to recharging local aquifers.

Compost can also be used in on-farm infrastructure projects, such as filter strips and grassed water ways. Filter systems work well around drain inlets, around storm drainage systems, surrounding receiving channels, and for sediment containment. Living filter systems, based on compost, trap sediment, bind and absorb pollutants, and degrade various toxic compounds with bacteria and fungi. Studies have shown that compost-based living filters can remove up to 99 per cent of coliform bacteria, 73 per cent of heavy metals, 92 per cent of nutrients, and 99 per cent of hydrocarbons.

Phosphorus

Compost applications can also help with the ever-growing, country-wide phosphorus problem.

As a general rule, phosphorus is tricky to manage. It binds very easily to other substances in the soil, making much of it unavailable to plants. As a result, growers may add phosphorus fertilizer, even when the soil already has high overall levels, in order to ensure that their crops have enough available P to ensure a good yield. If the soil becomes saturated (that is, all the P-binding sites are occupied), this can result in run-off of phosphorus into surface waters.

Since P is an important limiting nutrient for all plant growth, the result of this pollution is usually algae blooms in lakes, such as Lake Erie (see **Figure 26** in Chapter Two) and Lake Winnipeg. These have become serious issues in many parts of the country. However, there are solutions to this problem that don't require a sacrifice in yield.

Increasing evidence suggests that the P problem can be addressed biologically. The key is a large and diverse population of soil organisms.

Farmers who have developed very healthy soils report that tests indicate little or no P leaving their land. This is probably the result of a couple of factors: first, soil-health practicing farmers use cover crops, and having living roots in the soil all the time makes it more likely that any available P will be taken up by a plant, preventing immediate run-off; and secondly, when the main crop is growing in a healthy soil, the numerous and diverse organisms of the soil food web can take up P from the organic matter left behind by the covers (as well as any newly applied synthetic P) and thus prevent any major nutrient loss.

Moreover, these organisms then deliver the P to the plants in their root zones via the microbial loop (for more detail on how this works, see the section on carbon trading systems in Chapter 3, page 22). While these factors are likely the main reason for the reductions in P run-off from healthy soils, more applied research is needed, so that ever greater practical information is available on things like application rates, timing, and synergy between practices. In this way, farmers can feel confident that the soil-health approach will reduce their environmental impact.

Compost has a potentially important role to play here as it helps to support a large and diverse soil food web. However, it is important to use a mature compost product. Immature compost is similar to raw manure and digestates, in that it contains higher amounts of soluble nutrients than does mature compost. Accordingly, as with synthetic fertilizer, it is possible to create a phosphorus pollution problem with manures, digestates and immature compost. Alternatively, the P in stable, mature compost is mostly tied up and is made available by microbes in a slow-release process largely controlled by the crop, minimizing losses.

In summary, there is growing evidence that one of the ways in which P pollution can be averted, without sacrificing yield, is by combining the 4Rs approach to fertilizer use (see Chapter Seven), the use of cover crops to support soil health and mop up excess nutrients, and the application of mature compost to build the numbers and diversity of the soil food web.

Compost as Inoculant: Emerging Opportunities for Compost-Use Efficiency

Compost seed coatings

The concept of microbial seed coatings has been around for a long time. For instance, seeds treated with rhizobia (nitrogen fixing bacteria that form partnerships with leguminous plants) have been widely and successfully used for many decades. Until recently, however, the number of such applications has been relatively small in comparison to chemical seed treatments. However, this appears to be changing, with many agricultural input companies working to develop biological treatments (including seed coatings) for factors such as disease suppression, pest control, environmental adaptability, and growth promotion.

Results to-date have been mixed however as there are a number of barriers that need to be addressed if these new "technologies" are to be consistently effective. Issues include (but are not limited to):

- identifying the right microbes, or microbial "consortia" (see p. 26), to put on the seed as a coating, depending on the function(s) desired and the type of crop;
- finding the best method for attaching the microbes to the seed, without killing the microbes;
- keeping the microbial populations alive during seed storage and application;
- identifying the range of environmental conditions (e.g., soil type, moisture content, pH, etc.) within which the particular microbes will be active and deliver results.

One possible general solution to these issues is getting some attention lately. This approach is to coat the seeds with a slurry derived from local, or indigenous, compost. The thinking is that such a compost might have among its populations all of the microbial partners that a local crop would need and that they would be already adapted to local environmental conditions. This approach would address the first and last of the above issues. It would also help with the other two issues (i.e., microbe survival) because compost is a natural habitat for microbes and could sustain them during the interval between seed coating and seed planting.

Compost Pellets

Compost has been made into pellets many times by many different compost producers. However, in most, if not all cases, the purpose was simply to facilitate the application of the compost to land (pellets are easier to apply using conventional farm machinery than is unprocessed compost). This purpose for pelletizing, while useful, is rather limited. It does not take advantage of compost's unique ability to act as an inoculant, simply because the pelletizing process is usually not designed to ensure that the beneficial microbes survive.

Recently, however, pelletizing options that are more microbe friendly are emerging. Some companies are refining their pelletizing processes to allow high microbe survival rates inside the pellets. The theory behind this approach is that most agricultural land has been depleted in the variety of its soil life to some degree, resulting in reductions in fertility, disease suppression, and overall crop health. These compost pellets are made in such a way as to both preserve and enhance indigenous soil organisms. The goal is to address any deficiencies in the local soil food web and thus rehabilitate the natural system.

Compost Tea

The concept behind compost tea is that the beneficial organisms in compost can be extracted and then "brewed" in water by adding microbe foods while keeping the oxygen levels high enough to prevent the mix from becoming anaerobic. This increases microbe populations and produces a microbe-rich liquid that can be applied to soils and/or leaf surfaces. It is generally used as a way to suppress disease but many growers also feel that it is like a probiotic for their soil.

Perhaps the best way to think about compost tea is that it may offer a way to extend many of compost's benefits over much larger areas and at a lower cost. Although it will not provide much organic matter or nutrients, it may give the soil food web in any given soil a boost, with some scientific studies indicating that it can confer some of compost's disease suppression capacity to certain crops. This could be a valuable way to obtain some of the good things that compost has to offer when lack of availability or the cost of applying compost itself to a larger farm operation is prohibitive.

The Importance of Compost Quality

If compost's benefits primarily arise from its ability to nurture and support soil microbes, it is obviously very important that the compost be made properly so that it contains stabilized organic matter, a good balance of nutrients, and the right kind of microbial populations. As it turns out, all Canadian jurisdictions have rules in place to ensure that the compost from licensed facilities is properly manufactured – that it is, in fact, good compost.

Each province and territory has its own guidelines for compost quality or has adopted those produced by the Canadian Council of Ministers of the Environment (CCME). These guidelines protect the environment by ensuring that concentrations of trace metals, such as cadmium and mercury, as well as foreign matter and sharps, are within maximum limits. They also protect human health by ensuring that pathogen levels are within required limits. Maturity must also be measured as well as total organic matter and moisture. What all of this means is that users of compost from licensed facilities in Canada can be assured that the product they are buying is properly manufactured, mature, and safe for humans and the environment.

While these guidelines meet the requirements from the perspective of government regulators, the members of the Compost Council of Canada recognized a few years ago that something more was required. Different end uses of compost require different agronomic properties. For instance, the amount of soluble salt in a compost must be very low when it is used as a media for small plants and seedlings but can be higher when used as a top dressing or as a soil amendment. Similarly, the ratio of carbon-to-nitrogen in the compost (known as the C:N ratio) must be within a certain range (12-22) for most landscaping, turf topdressing, and planting media purposes, but can be considerably higher when the compost is used as a soil amendment (12-30) or for remediation (10-40).

About the CQA laboratory accreditation program:

Participating CQA-laboratories across Canada and the United States are involved in the CAP (Compost Analysis Proficiency) program, a laboratory quality assurance program to calibrate procedures and evaluate inter-lab method performance. The Test Methods for Examination of Composting and Compost (TMECC) forms the basis of the analytical test methods. CAP is administered by Dr. Robert Miller of Colorado State University.

The Council recognized that knowledge of agronomic parameters such as the above would help ensure that the right compost was used for the right purpose. This is the concept behind the **Compost Quality Alliance (CQA)** – to not only reflect government regulations but to go above and beyond to also test for the agronomic properties of compost and direct its usage appropriately.

The CQA is a voluntary initiative, open to all compost producers across Canada. Upfront operational audits as well as testing procedures are required of all CQA-members along with an ongoing sampling regime and product attribute focus and market sale. If you buy your compost from a CQA-certified producer, you will not only be able to get the results of the testing done to satisfy government requirements but also the testing done to meet CQA requirements – and the end-use recommendations that arise from that testing.