Healthy Soils and Human Health

Installment 2 in CHFS Healthy Soils Series

Healthy soils provide numerous benefits to our environment, from mitigating climate change to conserving water and improving water quality. But there's more: They also directly help you, as an individual, if you eat the food that's grown in them. Food from healthy soils is better for your health, thanks to a complex combination of factors.

To understand the relationship of soil to human health, we should first define what we mean by "healthy soil." The USDA's Natural Resources Conservation Service defines "healthy soil" as having continued capacity "to function as a vital living ecosystem that sustains plants, animals, and humans."[1] And in its list of the five essential functions of healthy soil, two most directly impact human health: Filtering and buffering potential pollutants; and storing, transforming, and cycling nutrients.

Overall, organic farming methods and healthy soils management coincide closely. The organic standards explicitly call for farming methods that build healthy soils.[2] The National Organic Program regulations require the farmer to "select and implement tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion."[3] Moreover, the "producer must implement a crop rotation including but not limited to sod, cover crops, green manure crops, and catch crops" that, among other things, maintain or improve soil organic matter content.[4]

The relationship is complicated by the fact that there are many conventional farmers who use one or more soil-building methods, such as reduced tillage, cover cropping, or rotational grazing (systematically moving foraging animals through sectioned parcels of land, where the animals themselves fertilize the soil, then are moved to another section so the first section can rest and re-grow). And it is possible to farm organically in ways that do not produce healthy soils, such as by using heavy tillage or continuous grazing, practices that some organic certifiers allow, particularly in large, "industrial-scale" organic operations.

But given that the defining principles of organic farming disallow use of synthetic chemical input, the correlation between organic farming and healthy soils is even more clear. Building healthy soils is far more difficult when a farmer is applying conventional herbicides, pesticides, and fungicides. Many of these chemicals harm or even kill the soil biology that is so critical for healthy soils.[5]

Consider glyphosate, for example, the most widely used herbicide in the world. Glyphosate is the active ingredient in Roundup® and more than 40 generic herbicides. Glyphosate was initially patented as a chelator (binding minerals in order to clean out boiler pipes of unwanted mineral

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[1] https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/

[2] https://www.ams.usda.gov/grades-standards/organic-standards

[3] 7 C.F.R. section 205.203(a)

[4] 7 C.F.R. section 205.205.

[5] *See, e.g.,* M. Rasul et al., Effect of pesticides on soil microorganisms, American Laboratory 33(23):24-25 (2001), https://www.researchgate.net/publication/289580547_Effect_of_pesticides_on_soil_microorganisms

buildup or scale), then as a herbicide, and then as an **antimicrobial**.[6] So, when applied to soil, glyphosate damages the microorganisms by making minerals unavailable to them. Just as significantly, when humans ingest plants treated with glyphosate, their own beneficial microbiome suffers similar harm. And research shows that harm is greater to beneficial organisms that to disease-causing microorganisms.[7]

In 2016 alone, an estimated 287 million pounds of glyphosate were used in the United States,[8] contaminating our food, soil, and water with a chemical that reduces the beneficial microorganism (the "good guys") populations while increasing the opportunistic organism populations. Beneficial microorganisms are vital for healthy soil *and* for human health. In contrast, management practices commonly used by organic growers, such as the use of composts and manures, cover crops, and diverse crop rotations, have been shown to increase biologically available forms of organic matter (carbon) and increase the activities of beneficial microorganisms.[9]

Within this discussion on the relationship between healthy soils and human health, we generally assume that we're looking at organically raised foods, while acknowledging the complicating factors along the way.

Benefit #1: Avoid toxins

Many people have some awareness of the health benefits of avoiding the toxins used in conventional agriculture and probably have some knowledge of glyphosate (or the Roundup brand). But they likely are unaware that glyphosate has been declared a Class 2A carcinogen by the WHO International Agency for Research on Cancer (IARC) ... or that glyphosate is far from alone in that category. Approximately 40 chemicals – classified by the IARC as known, probable, or possible human carcinogens – are used in EPA-registered pesticides currently on the market.

And yet, that IARC declaration doesn't even begin to capture the health impacts of these chemicals. In addition to the hundreds of "active" ingredients in agricultural chemicals, there are even more so-called "inert ingredients" that are not required to be safety tested. But they still

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[6] http://patft.uspto.gov/netacgi/nph-Parser

[7] Q. Mao et al., The Ramazzini Institute 13-week pilot study on glyphosate and roundup administered at human-equivalent dose to Sprague Dawley rats: effects on the microbiome. Environ. Health 17:50 (2018) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5972442/

[8] https://investigatemidwest.org/2019/05/26/breaking-down-the-use-of-glyphosate-in-the-u-s/

[9] M.M. Wander et el., Organic and conventional management effects on biologically active soil organic matter pools. Soil Si. Soc. Am. J. 58, 1130-1139 (1994); Marriott, E.M., and Wander, M.M. Qualitative and quantitative differences in particulate organic matter fractions in organic and conventional farming systems. Soil Biol. Biochem. 38, 1527-1536 2006); Fließbach et al., Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming, Agric. Ecosyst. Environ. 118, 273-184 (2007); S. Elmholt, Microbial activity, fungal abundance and distribution of *Penicillium* and *Fusarium* as bioindicators of a temporal development of organically cultivated soils. Biol. Agric. Hort. 13, 123-140 (1996); Gunapala and Scow, Dyanmics of soil microbial biomass and activity in conventional and organic farming system. Soil Biol., Biochem. 30, 805-816 (1998); Fließbach and Mader, Microbial biomass and size-density fractions differ between soils of organic and conventional agricultural systems. Soil Biol. Biochem. 32, 757-768 (2000).

have health impacts. For example, xylene is used as the inert ingredient in almost 900 pesticides "and has been associated with increased risk of brain tumors, rectal cancer, and leukemia."[10]

A 2017 United Nations Report stated that pesticides "are a global human rights concern," and that they cause "an array of harms."[11] The report notes that since chronic diseases generally have multiple causes and people are exposed to a complex mixture of chemicals, it is difficult to establish a direct causal link. "Even so, persistent use of pesticides, in particular agrochemicals used in industrial farming, have been connected to a range of adverse health impacts."[12] As noted in the report, pesticide exposure has been linked to cancer, Alzheimer's and Parkinson's diseases, hormone disruption, developmental disorders, and sterility. "They can also cause numerous neurological health effects such as memory loss, loss of coordination, reduced visual ability or reduced motor skills. Other possible effects include asthma, allergies, and hypersensitivity."[13]

Children in particular face serious risks. The combination of rapidly developing bodies, smaller size (so that the same amount of a pesticide creates a higher dose per unit body weight compared to adults), and lower levels of key detoxification enzymes, places them at much higher risk than adults. Childhood exposure to pesticides has been linked to impaired intellectual development, adverse behavioral effects and other developmental abnormalities.[14] Emerging research indicates that even low levels of exposure – such as through wind drift or residues on food – may be very damaging to children's health, "possibly leading to a lifetime of diseases and disorders."[15] Moreover, childhood cancer rates continue to rise,[16] and studies show that pesticide exposure during pregnancy and throughout childhood increase the risk of cancer among children. For example, researchers recently found that twice as much DDT exposure during childhood produced an almost three-fold increased risk of breast cancer.[17]

Even for adults, the residues on food raise concerns. Studies indicate that conventionally raised foods often contain multiple residues, thus resulting in consumption of a mixture of different pesticides.[18] A major "meta analysis" of 343 studies found that conventional crops had pesticide

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[10] President's Cancer Panel, 2008-2009 Annual Report, Reducing Environmental Cancer Risk, at page 46. https://deainfo.nci.nih.gov/advisory/pcp/annualReports/pcp08-09rpt/PCP_Report_08-09_508.pdf

[11] Report of the Special Rapporteur on the Right to Food, Human Rights Council, United Nations General Assembly (Jan. 24, 2017), Introduction at page 3, available at https://documents-dds-ny.un.org/doc/UNDOC/GEN/G17/017/85/PDF/G1701785.pdf

[12] 2017 UN report, Section II, page 4.

[13] 2017 UN report, Section II, page 5.

[14] Liu, Jianghong, and Erin Schelar. Pesticide Exposure and Child Neurodevelopment: Summary and Implications. Workplace Health & Safety 60: 235–243 (2012).

[15] 2017 UN Report at page 7.

[16] https://watermark.silverchair.com/djr077.pdf

[17] B. Cohn et al., DDT and Breast Cancer: Prospective Study of Induction Time and Susceptibility Windows, J. National Cancer Institute 111:803-810 (2019) https://academic.oup.com/jnci/article/111/8/803/52999241

[18] 2017 UN Report at page 8. *See also* President's Cancer Panel, 2008-2009 Annual Report, Reducing Environmental Cancer Risk, at page 46, https://deainfo.nci.nih.gov/advisory/pcp/annualReports/pcp08-09rpt/PCP_Report_08-09_508.pdf (noting that in USDA's most recent testing of more than 80 types of foods, "Only 23.1 percent of samples had zero pesticide residues detected, 29.5 percent had one residue, and the remainder had two or more.")

residues four times more frequently than organic.[19] And while far more research is needed, it is known that at least some pesticides have synergistic interactions – so that consuming small amounts of multiple pesticides can be far more harmful than the simple amounts alone would indicate.[20] Washing produce doesn't solve the problem, since many pesticides are taken up through the roots and distributed throughout the plant.

According to the 2009 report[21] from the prestigious **President's Cancer Panel**, the link between pesticides and cancer has been significantly underestimated. Specifically, the Panel's report stated: "The entire U.S. population is exposed on a daily basis to numerous agricultural chemicals. Many of these chemicals are known or suspected of having either carcinogenic or endocrine-disrupting properties."[22]

Benefit # 2: Increased nutrients

Setting aside the dangers of chemical toxins in our food, let's look closer at the nutritional value of food grown in healthy vs. unhealthy soil.

We know that nutrient levels in vegetables have generally declined over the last 50-70 years.[23] Some recent studies have attempted to determine how much of that decline is due to farming methods and how much is due to genetics created by selective breeding of plants during that time period. Both factors could affect the final nutrient levels because of the same basic principle: The push for greater production has meant that obtaining the same amount of nutrition that was once present in "X" quantity of a crop now requires a larger quantity of the crop; essentially a "dilution" effect.[24]

So, do organic crops show *less* of a decline and/or higher nutritional values? When we look at the compounds that scientists have studied for the longest time, such as calcium, iron, and riboflavin, the studies are mixed. Overall, they support the claim that foods grown organically in healthy soils have somewhat higher levels of some of the key nutrients, although it's not clear how significant the increases are.[25] A number of things could contribute to the increased nutrient

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[19] M. Baranski et al., Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systemic literature review and meta-analyses. Br. J. Nutr. 112: 794-811 (2014), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4141693/

[20] 2017 UN Report at page 8

[21] President's Cancer Panel, 2008-2009 Annual Report, Reducing Environmental Cancer Risk, Letter to President Obama, https://deainfo.nci.nih.gov/advisory/pcp/annualReports/pcp08-09rpt/PCP_Report_08-09_508.pdf

[22] President's Cancer Panel, 2008-2009 Annual Report, Reducing Environmental Cancer Risk, at page 43 https://deainfo.nci.nih.gov/advisory/pcp/annualReports/pcp08-09rpt/PCP_Report_08-09_508.pdf

[23] *See, e.g.,* D. Davis, M. Epp, and H. Riordan, Changes in USDA Food Composition Data for 43 Garden Crops, 1950-1999, J. Am. College of Nutrition, 23(6) 669-682 (2004).

[24] D. Davis, Declining Fruit and Vegetable Nutrient Composition: What is the Evidence? Hort. Science Vol. 44(1) (Feb. 2009).

[25] Woese et al., A comparison of organically and conventionally grown foods – results of a review of the relevant literature. J. Sci. Food. Agric. 74: 281-293 (1997); V. Worthington, Nutritional quality of organic versus conventional fruits, vegetables, and grains. J. Altern. Complem. Med. 7:161-173 (2001); E. Rembialkowska, Quality of plant products from organic agriculture. J. Sci. Food. Agric. 87:2757-2762 (2007); D. Lairon, Nutritional quality and safety of organic food. A review. Agron. Sustain. Dev. 30:33-41 (2010); Hunter et al., Evaluation of the micronutrient composition of plant foods produced by organic and conventional agricultural methods. Crit. Rev. Food Sci. Nutr.

levels in organically raised foods: increased available trace elements from organic inputs (compost, manure, kelp meal, etc.); increased uptake due to improved cation/anion balance; or increased availability of nutrients through enhanced biological activity.[26] Indeed, the mixed results may be due to the fact that, as mentioned at the beginning of this article, farming practices are a spectrum, not an either/or of "organic/healthy soils" versus "conventional/degraded soils."

There's another issue besides how much of a mineral is in a plant: How much of that mineral can be absorbed when a person eats it? This brings us back to the glyphosate issue. As we said, glyphosate "chelates" (binds) calcium, magnesium, and multiple other important minerals. Even a very small amount of glyphosate can make these chelated minerals bio-unavailable, both to the plant and to the person consuming it. Given the impact, this is not just an issue with those plants intentionally sprayed with glyphosate (such as the genetically engineered crops that are designed to survive herbicide application), but also on "non-target" plants onto which glyphosate drifts.[27]

Benefit #3: Increased "healthy stuff"

The discussion above focuses on the nutrients that have been studied for many decades. But there are thousands of other substances in the food, many, if not all, of which have some sort of biological activity. These include signal transducers, hormones, sterols, enzymes, enzyme inhibitors, and polyphenols, among others. These substances are whatever the plant or animal needs to stay alive, reproduce, and protect itself from predators, enemies, and disease.

The evidence in favor of higher nutrition from foods grown organically (thus, in healthy soil) is much stronger in this arena. A 2014 analysis looking at multiple scientific studies found that the presence of a wide range of antioxidants such as polyphenolics were substantially higher in organic crops/crop-based foods, including phenolic acids, flavanones, stilbenes, flavones, flavonols and anthocyanins.[28]

Consider garlic, a food well-known for its health benefits. The USDA identifies 67 nutritional components in raw garlic, with a focus on manganese, Vitamin B, and selenium. But garlic contains more than 2,306 distinct chemical components. These include luteolin, a compound that appears to protect against cardiovascular disease.[29]

51:571-582 (2011); Palupi et al., Comparison of nutritional quality between conventional and organic dairy products: a meta-analysis. J. Sci. Food Agric. 92: 2774-2781 (2012); Baranski et al., Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systemic literature review and meta-analyses , Br. J. Nutr. 112:794-811 (2014).

[26] J.R. Reeve et al., Organic Farming, Soil Health, and Food Quality: Considering Possible Links, Advances in Agronomy 137:319-368 (2016), http://dx.doi.org/10.1016/bs.agron.2015.12.003.

[27] S. Eker et al., Foliar-Applied Glyphosate Substantially Reduced Uptake and Transport of Iron and Manganese in Sunflower (Helianthus annuus L.) Plants, J. Agric. Food Chem. 2006, 54, 26, 10019–10025 (2006), https://doi.org/10.1021/jf0625196; I. Cakmak et al. Glyphosate reduced seed and leaf concentrations of calcium, manganese, magnesium, and iron in non-glyphosate resistant soybean, https://core.ac.uk/download/pdf/11741277.pdf;

[28] Baranski et al., Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systemic literature review and meta-analyses , Br. J. Nutr. 112:794-811 (2014).

[29] Barabasi, A., G. Menichetti, and J. Loscalzo, The unmapped chemical complexity of our diet, Nature Food, https://doi.org/10.1038/s43016-019-0005-1.

As of August 2019, some 26,625 distinct biochemicals have been identified in food.[30] Why is it so complex? All food comes from living organisms in which every compound interacted to produce biological systems. It seems fair to assume that the vast majority of components of plant and animal-based food is functional, performing some kind of biological activity or purpose.

All living organisms require a large number of biochemicals to grow and survive. Animals, such as humans, make these biochemicals from the raw ingredients they consume. Plants have an even greater need in many ways, since they also must rely on compounds they make as their defense from predation (since they can't run away or hide from the creatures that eat them). Plants' natural defenses require an extensive array of what's called "secondary metabolism" that produces a wide range of flavonoids, terpenoids, and alkaloids. Polyphenols – which studies indicate provide health benefits in tea and other plants – are the product of that secondary metabolism. And the number of secondary metabolites may be even greater than the 26,000 biochemicals that have been identified in foods.

These "plant secondary compounds" support human health in (at least) two different ways: by weakening pathogens that hurt humans[31] and via direct positive effects. For example, plants synthesize antioxidants to protect themselves against the oxygen free-radicals produced during photosynthesis – those same antioxidants help protect people from free-radicals produced from ultraviolet exposure or from pollutants such as smoke or car exhaust.

Or consider garlic again. Fresh garlic contains an amino acid called alliin. When the clove is crushed or chopped, an enzyme, alliinase, is released. Alliin and alliinase interact to form allicin, which is considered the major biologically active component of garlic. Many scientific studies have shown that the allicin in garlic may offer a variety of health benefits, from lower cholesterol and improved blood pressure control to prevention of atherosclerosis, a disease caused by fatty deposits in arteries.[32]

CONCLUSION

Healthy soils are complex entities … and the results are complex as well. Yet for all the complicating factors, a clear picture still emerges: Eating food grown organically in healthy soils both reduces your exposure to toxins and nourishes your body for greater health. To maximize these benefits, buy from farmers who you know are using healthy soil methods. Know your farmer, ask questions, and thrive!

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[30] Barabasi, A., G. Menichetti, and J. Loscalzo, The unmapped chemical complexity of our diet, Nature Food, https://doi.org/10.1038/s43016-019-0005-1. (citing https://foodb.ca/compounds)

[31] See e.g., A.K. Pcman, Biological activities of sesquiterpene lactones. Biochem. Syst. Ecol. 14:255-281 (1986); Hocquemille, R. et al., Isolation and synthesis o espinatanol, a new antiparasitic monoterpene. J. Nat. Prod. 54:445-452 (1991)

[32] https://www.verywellhealth.com/the-benefits-of-allicin-88606