frontiers | Frontiers in Soil Science

TYPE Opinion
PUBLISHED 15 July 2024
DOI 10.3389/fsoil.2024.1403795

OPEN ACCESS

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RECEIVED 20 March 2024
ACCEPTED 26 June 2024
PUBLISHED 15 July 2024

CITATION
Perler BK (2024) Soil ecology, food systems, and organic waste: the critical network nobody is talking about.
Front. Soil Sci. 4:1403795.
doi: 10.3389/fsoil.2024.1403795

Soil ecology, food systems, and organic waste: the critical network nobody is talking about

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KEYWORDS

soil, soil ecology, health, food system, food, greenhouse gas, planetary health, climate change

Food change

Why do we care so much about food? On the surface its very simple – we need nutrients for every physiology process but is much more than just fuel. It represents stories passed on from generation to generation, it is at the core of every culture and many social experiences are structured around food. We seek out food and it is integrated in our dopamine reward system. But food has changed dramatically in the past several decades. Modern agriculture and food science practices have dramatically changed what food looks like and there are profound consequences to these changes. Although our biochemical understanding of micronutrient deficiencies has expanded greatly and with modern food science we can now easily and accessibly address these, it has also led to highly palatable energy dense ultra-processed food that is ubiquitous in our society. For example, food swamps are communities that are not close to health food options such as supermarkets and farmers markets, with increased abundance of fast-food restaurants, convenience stores, bodegas (1) which have more energy dense ultra-processed food options than fresh nutrient rich produce (2). Studies have demonstrated a strong association between food swamps and obesity, including being a stronger predictor of obesity than a lack of full-service grocery stores (2). It is no coincidence that the age of access and excess of ultra-processed calorie dense foods has seen alarming trends in obesity (3) and cardiometabolic disease (4). Obesity is a complex multifactorial disease with numerous variables that impact the risk of development and progression including genetics, epigenetics, environmental, and socioeconomic factors, to name a few. Of the factors that contribute to obesity, calorie excess and ultra-processed food consumption are major contributors (5). Our trajectory is deeply concerning with current obesity projections of 1:2 US adults having obesity by 2030 (6). Obesity is linked to significant health care utilization resulting in over 170 billion dollars in associated annual healthcare costs (7).

Soil depletion

Although obesity is one complication of our modern food and agricultural systems, there are many other issues that arise including environmental implications of big/commercial agriculture, chemical fertilizers, synthetic pesticides/herbicides and land being prioritized for domestic livestock. Not only are we eroding our health, but also the world around us. While diets rich in fiber and produce such as the Mediterranean diet are associated with increased gut microbiota diversity (8), emulsifiers which are common food additives in the modern western diet, are associated with reduced microbiota diversity (9). Additionally, some studies demonstrate obesity is associated with a reduced diversity of the gut microbiota (10). Just as our gut microbiota are losing diversity, so too are we seeing loss of biodiversity in numerous other ecosystems including soil resulting in a reduction in functional capacity and ability to tolerate disturbances (11). It is no surprise that our health has diminished as we have replaced plant-based produce with synthetic preservatives, processed grains and refined sugars (12). The soil equally suffers as we apply large batches of chemical fertilizers and pesticides that leads to a reduction in soil biodiversity, and this impacts the health of everything downstream (11). When plants are let to grow as nature intended; in a symbiotic relationship with soil microbes, they produce more health promoting phytochemicals such as flavonoids, as has been demonstrated by the increased production of flavonoids by tomatoes treated with the soil microbe *Trichoderma harzianum* which has been associated with resistance to fungal infections (13). Unfortunately, as soil microbial biodiversity is reduced, plants become less resilient to the unrelenting external environment such as the ability of plants to prevent disease from pathogens (13, 14). These plants then become reliant on human intervention with application of synthetic pesticides to prevent infestation and disease. Additionally, with modern agricultural practices, there has been an observed reduction in the nutrient density of crops including fruits, vegetables and grains (15–17). These less resilient, lower nutrient density plants then enter ours and other food chains with unclear health consequences. Further, we often process these plants into unrecognizable forms which results in further reduction of nutritional quality (18).

Food waste/GHG emissions

Another fundamental component that is critical to consider in this dynamic network is organic waste and greenhouse gas emissions. Greenhouse gases are a major driver of climate change. Methane is a greenhouse gas generated by a variety of processes including the decay of organic waste. It is estimated to account for 12% of the annual greenhouse gas emissions in the United States and is approximately 28 times more potent than carbon dioxide over a 100-year period (19). Approximately 1/3rd of food is wasted annually with a recent EPA report estimating this waste to be in the order of 150 million tons (20). Concerningly, the majority of this food waste is being discarded in landfills, which slowly decays into methane. Although some of this methane is captured and converted to biogas, most of this becomes wasted waste which does not enter back into the ecosystem where it could provide vital nutrients to soil. We also must take into consideration the impact of domestic livestock on greenhouse gas emissions. In the United States, livestock generates up to 1.4 billion tons of manure annually (21), and although this can be used as a soil amendment, large quantities of methane get trapped into the atmosphere as a result. Additionally, approximately 80% of agriculture land is used for domestic livestock worldwide. This includes land used for grazing and growing crops for animal feed (22). Together, food waste and manure production with domestic livestock enteric fermentation account for greater methane emissions than petroleum, natural gas, and coal-based systems annually (23).

Interconnection

We cannot think about these systems in isolation. Each system, including the food system, health system, soil ecological system and climate system, interfaces with one another to generate a dynamic network which we are profoundly disrupting, to the point where each system might not be able to continue compensating. We need to recognize how fundamental these issues are for one world health. Many of these relationships we are disrupting have been established and flourishing for thousands to millions of years and within a few short decades, we think we can miraculously make it better. Of course, our shortsightedness has many unforeseen consequences that are now staring at us in the face. We need to listen to the world around us and not be so limited in our perspective. We as humans have the ability to generate tremendous prosperity, but our suffering continues to grow in the form of debilitating chronic disease as the world around us is also slowly suffering. And while we go on our journey, so much around us is destroyed in the process. We can live in prosperity with all species, and we can heal the environment along with ourselves at the same time.

Possible solutions

By thinking about the soil, we can think of ways to start healing. With sustainable agricultural practices, we can promote soil health while sequestering carbon, a critical endeavor that is on the forefront of most countries policies. We need to give back in a way that replaces what we take. Not in the form of synthetics, but in the form of cover crops, crop rotations, and limited to no till farming, as a few examples, which help to rejuvenate the soil that has been so kind to us. Cover cropping and crop rotations are critical rejuvenation endeavors which help to improve soil architecture, increase fertility including nitrogen fixation with legume intercropping along with prevention of erosion (24). Other powerful benefits of this process have been demonstrated with legumes including increased soil carbon sequestration, microbial biomass (25) and increasing yield of main agricultural cash crops (26). No till farming prevents disturbances to soil and soil architecture allowing for nature to naturally decompose, churn and aerate the soil. This leads to increased water retention capacity of soil, nutrition cycling and retention of organic material (27), while helping to sequester carbon in surface soil (28).

We also have the opportunity to provide the soil with much needed nutrition from organic waste, rather than the commonly applied synthetic petroleum-based chemical fertilizers that are ubiquitous in commercial agriculture. The tremendous amount of food that is wasted annually can be recycled through techniques such as composting and biochar production. Aerobic composting utilizes oxygen to decompose organic waste into a nutrient dense soil amendment which helps to improve soil fertility and structure. Composting also provides increased water absorption and acts as a slowly releasing nutrition reservoir (24). Biochar is generated when organic waste is heated at high temperatures in low oxygen states. This generates a carbon rich highly porous material that offers numerous benefits to soil. Biochar helps to improve the structure of soil including biophysical and biochemical properties. It allows for long term carbon sequestration, it can adsorb heavy metal contaminants and pollutants to reduce entry into our food system, increases soil water retention capacity in part due to the high surface area of the structure, and also promotes increased microbial activity (29). While these are both promising and impactful resources, recycling food waste can go even further including upcycling to repurpose the food and keep it in the food system, a recommendation the EPA thinks needs further attention (30).

Also, continual efforts need to be made to shift our dietary habits to a greater focus on produce allowing us to reduce our reliance on livestock which are major contributors to greenhouse gas emissions. Conceptually, this is a logical and necessary solution, but the applications to achieve this goal are complex and often need to be individualized. Supplemental nutrition assistance programs including Women, Infants and Children (WIC) and National School Lunch Program (NSLP) have been demonstrated to significantly improve diet quality (31). These efforts are important, but as the price of produce continues to increase with inflation, budgetary allocations to programs like this need to be expanded. An example of this in action is the SNAP Eat Well, Be Well Pilot Incentive program which has been implemented statewide in Rhode Island. This incentive program provides $0.50 in SNAP benefits for every $1 spent at participating retailers on qualifying produce (32). Produce prescription programs (PPR) provide prescriptions, vouchers, or gift cards for fruits and vegetables which can be redeemed at grocery stores or farmers markets. PPRs are customarily provided by healthcare providers. PPRs have been demonstrated to improve dietary quality (33, 34) along with enhancing food security (34). Although clinically relevant outcomes have been mixed (33), a recent study demonstrated that PPR significantly reduce blood pressure, BMI and hemoglobin A1C in adults with cardiovascular disease (34). More research needs to be completed on these programs, but efforts like these that help to increase accessibility and affordability of nutrient rich produce is a critical endeavor to make necessary changes for a sustainable future. Other promising efforts include community gardens, urban farms and urban food forests. Community gardens are associated with increased fruit and vegetable consumption (35) along with being associated with a lower BMI than those who do not participate in community gardens (36). Models have demonstrated that urban farms and food forests can generate a significant amount of produce that can provide revenue to the community, aid in urban cooling, and in the case of food forests, they can help to mitigate climate change (37). There is no single solution, but rather numerous collective efforts that are necessary to integrate together in order for us to change our approach to food. And by doing so we can not only change ourselves, but also the world around us.

Collectively, we need to take a step back and think about the relationship of these systems, not individual and isolated systems with rigid boarders, but a dynamic fluid interconnected network. By healing the soil with these practices, we can not only improve the health of plants and organisms that live directly in the soil, which allows for better nutritional quality for plants that enter into our food system, but also increase agricultures yields which helps to improve food security for all. And at the same time, we can increase our ability to combat greenhouse gas emissions and help to rebuild what we have damaged. It is our duty for not just our species, but for all species that call this beautiful planet our collective home.

Author contributions

BP: Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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