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A One Health Circular Bioeconomy: The Case for Composting Amid a Protein Transition

By Eric Christine*

Executive summary:

- Ultra-processed foods account for approximately half of the daily calories consumed by Americans, displacing essential dietary fiber and elevating chronic disease risks.
- The United States (US) wastes nearly 30 percent of its food supply, generating a $380 billion economic loss that costs the typical four-person household over $2,900 annually.
- Highly perishable produce is the most wasted food category nationwide. This waste is primarily discarded in landfills and incinerators, emitting greenhouse gases.
- Composting food scraps and manure offers a sustainable way to offset nutrient losses, though consideration must be given to emissions from suboptimal operations strategies.
- Transitioning the national diet away from resource-intensive meats toward plant-based proteins and mushrooms simultaneously improves human health and environmental resilience via increased fiber intake and food waste reduction.
- Redirecting agricultural residues and fibrous food scraps into compost and fungi-based food production creates a circular bioeconomy, generating nutritious alternative proteins from organic waste.
- Federal cap-and-trade policies on agricultural nitrous oxide emissions, paired with state-level value-added taxes on resource-intensive foods, can induce shifts in production practices and consumer choices while providing the financial leverage necessary to invest in compost infrastructure.

Bottom Line: To resolve the mounting climate and health externalities of the US food system, policymakers must pair expanded composting infrastructure with economic incentives that simultaneously drive waste reduction and dietary shifts.

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I. Introduction

Microbial organisms underpin the global food economy by facilitating human and animal digestion, supporting plant growth, and maintaining diverse soil ecosystems. However, in the United States (US), two persistent gaps exist that negatively impact both microbiological and macroeconomic systems: insufficient fiber intake, and nutrient losses caused by an excessive amount of food waste. These two interconnected problems can be rectified through policy reforms and the adoption of more regenerative practices, moving the US toward a more circular bioeconomy—improving metrics of health, agricultural productivity, and economic sustainability.

This policy brief examines how dietary change and increased composting can work as complementary demand- and supply-side strategies for human and ecological health benefits. Using the US food landscape as a case study, it offers holistic insights for linking food consumption and disposal to agricultural soil regeneration and protein generation. The principles of circularity and One Health are embodied by multifaceted policy frameworks designed to optimize microbial environments across the nutrient supply chain.

II. Food and The Microbiome

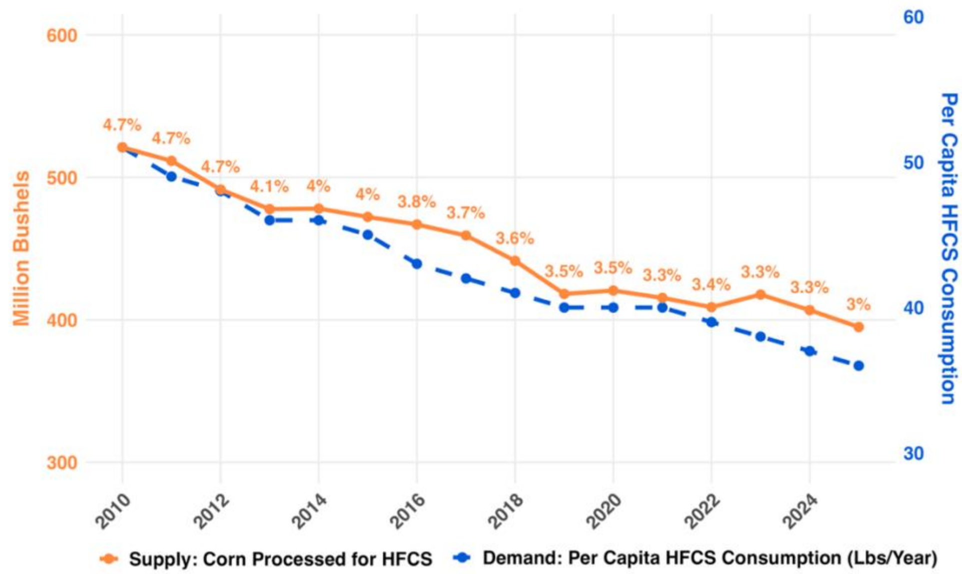
A. Dietary Landscape and Ultra-Processed Foods

There is no universal definition for ultra-processed foods (UPFs). They are generally described as foods that are highly refined or industrially processed, often containing additives such as colors, diluted flavors, or emulsifiers (Medin et al., 2025). The degree to which a food is processed or broken down does not inherently make it less healthy (Dicken, 2026). Nonetheless, commercial UPFs frequently serve as delivery vehicles for energy-dense nutrients (Vitale et al., 2023).

In the context of UPFs, high-fructose corn syrup (HFCS) is a widely used sweetener for processed foods and beverages in the US (Tadisina et al., 2026). Frequent consumption of HFCS-sweetened foods and beverages is linked to adverse chronic health conditions, increasing inflammation, adiposity (body fat), and cancer risk (Johnson et al., 2026; Aoyagi et al., 2025). Due to these factors, the use and consumption of HFCS has decreased substantially in recent years, as shown in Figure 1 below.

The declining proportion of corn going toward HFCS production can be attributed partially to growing consumer awareness of the prevalence of HFCS in the modern food system. Today, as many as 93 percent of Americans not only know what it is, but 16 percent are willing to pay a price premium for HFCS-free foods (Sarasty & Amin, 2026). Awareness of the health impacts has also grown in recent years: approximately 84 percent know that sugar-sweetened beverage consumption is linked to weight gain while 78 percent know about the heightened risk of type 2 diabetes (Hunter et al., 2024).

Figure 1. HFCS Supply and Demand, 2010 – 2025



Source: *US Department of Agriculture (USDA) Economic Research Service ([ERS]; 2026a)*

Note: *Orange percent values represent the proportion of corn in millions of bushels used to make HFCS for each marketing year. Per capita HFCS consumption is estimated using retail weight values (in dry pounds per calendar year) for food and beverages as a proxy, then dividing that value by the estimated total US population of the given year.*

These shifting consumer preferences have notably altered the national supply of HFCS, but some suppliers are merely substituting other refined sugars like cane sugar for HFCS (Kesslen, 2025). Despite lower HFCS production and consumption, UPFs still represent about 50 percent of the food products purchased by US households (Popkin et al., 2024). Ultimately, the decline in HFCS represents market substitution rather than a significant dietary shift, leaving the broader public health harms of UPFs still unresolved.

From 2003-2023, UPFs accounted for approximately 50 percent of the daily caloric intake of Americans, negatively influencing markers of overall health such as inflammation (Tian et al., 2025). Adverse chronic health conditions associated with UPF consumption include cardiovascular disease, type 2 diabetes, cancer, and obesity—which are among the costliest diseases in the US today (Willett et al., 2026; Du et al., 2024; DeVito & Sheean, 2025; Godsey et al., 2025; Temple, 2024; Nieto & Saucedo-Delgado, 2025).

While some UPFs can be relatively neutral or even healthy (e.g., whole wheat bread), broad UPF consumption displaces the intake of dietary fiber and protein—increasing refined sugar and saturated fat consumption instead (Martini et al., 2021). Plant-based UPFs have a preferable

nutrient profile as compared to unprocessed and processed meat products, which are high in saturated fat and lack fiber entirely (Del Carmen Fernández-Fígares Jiménez & López-Moreno, 2025).

The 2025-2030 Dietary Guidelines for Americans (DGA) advises an explicit reduction in UPF consumption (USDA & HHS, 2026). At the same time, however, the DGA advises consuming 1.2 to 1.6 grams of protein per kilogram (g/kg) of bodyweight per day—a recommendation criticized for its emphasis on increasing meat and dairy food intake (Giosuè et al., 2025). The 2025 Dietary Guidelines Advisory Committee (DGAC), a group of experts convened to inform the DGA, stated that while Americans typically consume more "Total Protein Foods" than is necessary—specifically meat, poultry and eggs—they often fail to consume enough dietary fiber, found primarily in plant-based foods. The committee recommended that Americans should increase their intake of legumes such as beans and peas (DGAC, 2024).

This aligns with evidence illustrating the nutritional and public health benefits of shifting diets toward more plant-based protein and fiber consumption (Qi et al., 2022; Stavitz et al., 2025; Guarneiri et al., 2025). Since dietary patterns characterized by greater plant intake correspond to more sustainable agro-economic supply chains, shifting consumer choices also has implications for creating more circular economies (Alblaji et al., 2026).

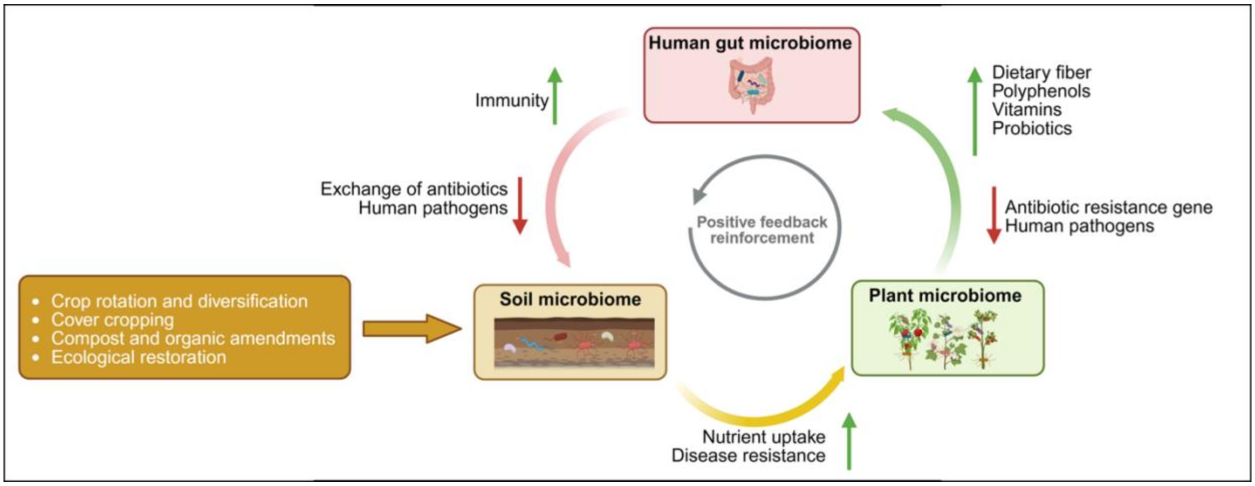
B. Circular Microbiomes

Fiber is essential to the human diet due to its direct impact on the human gut microbiome—the collection of trillions of bacteria, archaea, and other microorganisms inhabiting the digestive tract (Muigano et al., 2025). Evidence suggests that dietary patterns characterized by high fiber and low UPF intake result in the proliferation and diversification of beneficial microbial species in the gut (Gjermeni et al., 2025; Egas-Montenegro et al., 2026). Beneficial species produce short-chain fatty acids (SCFAs)—metabolites that regulate the immune system, neurotransmitter production (which affects mood), and energy levels—by fermenting dietary fibers known as prebiotics (Bedu-Ferrari et al., 2022; Sanz et al., 2025).

The biological mechanisms underpinning digestion also underpin the macroeconomics of circular food systems (Couradeau et al., 2025). Microbes span humans as well as soil ecosystems, plants, and animals, representing a One Health microbiological continuum, illustrated in Figure 2 below. In the same way that societies exchange resources in a global economy, microbes "trade" in the biological market of metabolites, exchanging SCFAs for energy (Mostafa et al., 2024). Besides fiber, though, gut microbes digest molecules like choline in meat products, producing trimethylamine, which the liver then modifies to trimethylamine N-oxide (TMAO)—a pro-inflammatory molecule that can increase the risk of cardiovascular diseases (Haas et al., 2025; Ferreira et al., 2026).

By consuming whole plant foods that are high in both protein and fiber, such as legumes and mushrooms, Americans can substantially improve metabolic health outcomes through optimizing the gut microbiome (Wu et al., 2025; Riad et al., 2026). Moreover, consuming complementary whole plant foods such as grains during meals creates a blend of protein that extends the benefits to health without compromising affordability (Soh et al., 2026). Foods like beans and lentils are also remarkably shelf-stable, surpassing animal foods in terms of perishability—meaning dietary choices also impact food waste reduction goals (Didinger & Thompson, 2020; Lori et al., 2023; Nguyen et al., 2025).

Figure 2. Circularity of Microbiomes Across Human, Soil, and Plant Ecosystems



Source: *Ma et al., 2025*

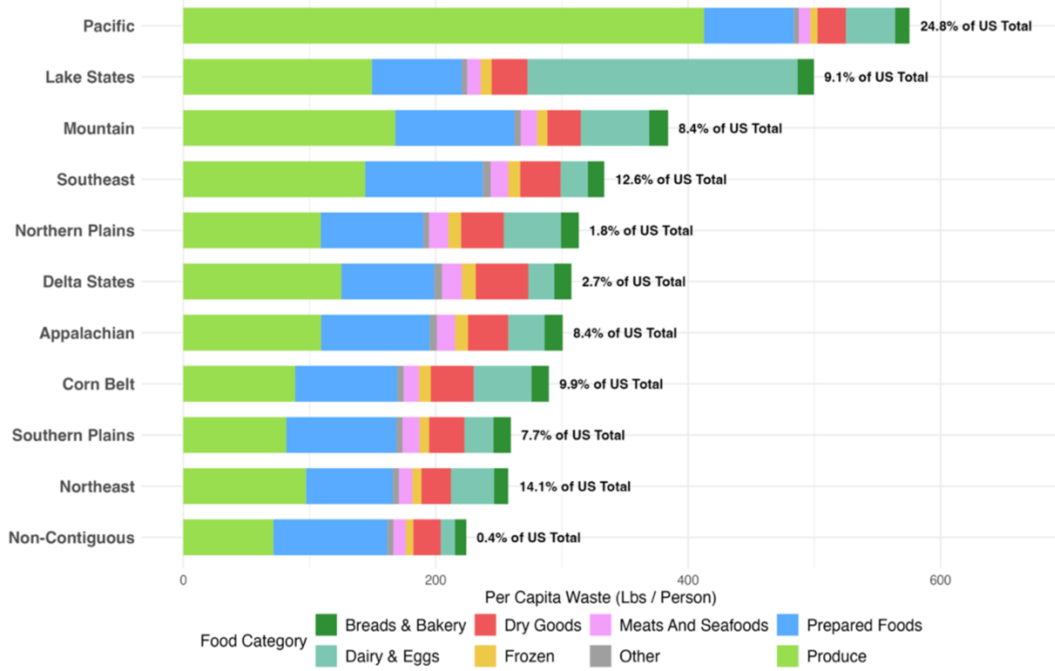
Note: *The authors acknowledge that implementing practices to advance healthy soils creates positive feedback loops for microbiomes across ecological systems (» soils → plants → humans »).*

III. US Food Waste: Environmental and Health Externalities

Food waste (also 'food loss,' or 'food surplus,' depending on the context) is particularly relevant to building circular economies. For instance, organic waste derived from corn harvesting or processing can be reintegrated into various inputs to agriculture and industry through a process called valorization (Sarker et al., 2024; Bhardwaj et al., 2025). Such inputs include compost, animal feed, and biofuel (Machado et al., 2026).

In the US, it is estimated that food waste costs a four-person household $2,913 per year, representing 11 percent of the typical American household's yearly food expenditures (Kenny, 2025). Almost 30 percent of all food produced in the US is wasted, presenting an immense opportunity cost upwards of $380 billion (Rethink Food Waste through Economics and Data [ReFED], 2026a). Produce is the most wasted food by category, with per capita food waste highest in the Pacific region in 2024, as shown in Figure 3.

Figure 3. Per Capita Food Waste by USDA Production Region and Food Category, 2024



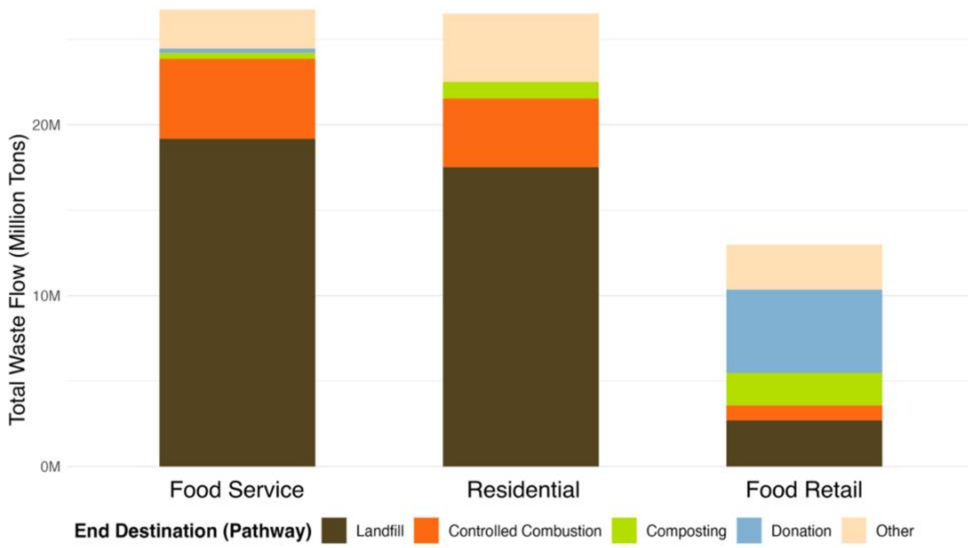
Source: *ReFED, 2026b; US Census Bureau, 2026*

Note: *Each bar represents total annual food waste generated within a USDA Farm Production Region divided by that region's cumulative population, converted to pounds per person, and disaggregated by food category. Food categories representing less than 2 percent of a region's total waste (including ready-to-drink beverages) are aggregated into "Other." Percentage labels indicate each region's proportional contribution to total US food waste generation by weight.*

Produce spoils more quickly than other foods due to its higher water content, greater microbial cohabitation on plants relative to processed foods or meats, and direct exposure to factors like humidity and temperature (Mafe et al., 2024). As shown in Figure 4, a staggering amount of food in the US—both unsold and sold—is sent to landfills, with the next most common destination being controlled combustion facilities.

The decomposition of organic material in landfills emits greenhouse gases (GHG) like methane while controlled combustion (incineration) emits carbon dioxide (Esmaeilpour Moghadam et al., 2025). The continuous emission of these gases adversely impacts climate change as well as ambient air quality, causing health issues for neighboring communities through exposure to and inhalation of particulate matter (World Health Organization, 2025).

Figure 4. US Food Waste Generation and
End-of-Life Pathways by Economic Sector, 2019



Source: *EPA, 2023*

Note: *Annual US food waste generation by economic sector and end-of-life pathway. Food Bank generation is excluded to prevent double-counting upstream donations. The "Other" category aggregates minor destinations like anaerobic digestion, bio-based materials, and animal feed.*

For the American and global food system, there is an impetus to shift waste dumping and dietary practices toward those that benefit people and planet alike (Rai et al., 2025; Rockström et al., 2025). Policies that attempt to rectify the harms of food waste streams must also encourage a simultaneous shift in dietary choices to strengthen the creation of a circular economy. Composting is one regenerative practice that governments, farmers, and households can leverage to encourage the adoption of more sustainable diets while also closing the nutrient gap exacerbated by food waste.

IV. Composting for Nutrient Circularity and Public Health

A. Manure and Agri-Food Waste Valorization

Composting converts organic material (e.g. manure, food waste, animal carcasses) into useful soil amendments through approaches such as aerobic decomposition, which uses microbes or worms to break down plant material or animal manure. The practice has been identified as central to building a more circular economy not only in the US but globally (Farhidi et al., 2022; Serafini et al., 2026).

Amidst rising environmental concerns related to nutrient runoff and nitrous oxide (N_2O) emissions in the US, compost offers a potentially viable and scalable alternative to nitrogen (N) fertilizers for optimizing crop nutrition and soil health (Goswami & Tshabalala, 2026; Cordeiro & Sindhøj, 2024; Pajura, 2024; Shahzad et al., 2025). However, using municipal solid waste compost as a fertilizer substitute carries important drawbacks, such as the presence of toxic elements and potential nutrient losses (Cao et al., 2023).

Compost piles themselves are volatile with respect to GHG emissions, subject to constraints including initial carbon-to-nitrogen ratios which can influence the decomposition process profoundly (Shen et al., 2026). Other factors, such as the feedstock used, bulking agent applied, and pile aeration rate, can influence the degree to which nutrients are lost to the environment. As detailed in Table 1, executing single-gas optimization strategies in compost operations for certain feedstocks incurs negative biochemical trade-offs. For instance, when composting swine manure, optimizing solely to control ammonia (NH_3) subsequently increases N_2O and methane emissions, ultimately generating a massive net-positive carbon footprint.

Table 1. Percent GHG Reductions and Net Carbon Footprints of Gas-Specific Optimal Compost Strategies Across Four Feedstock Types

Feedstock	Optimization Target	NH_3 (%)	N_2O (%)	CH_4 (%)	CO_2 (%)	CO_2-eq (t^{-1})
Food Waste	Minimize Ammonia (NH_3)	1.55	0.48	0.05	19.01	-31
	Minimize Nitrous Oxide (N_2O)	8.73	0.06	0.13	18.56	74
	Minimize Methane (CH_4)	13.69	0.87	0.00	30.59	185
	Net Carbon Footprint Strategy	2.36	0.33	0.04	10.74	-49
Cattle Manure	Minimize Ammonia (NH_3)	1.03	0.10	0.18	18.54	128
	Minimize Nitrous Oxide (N_2O)	6.59	0.00	0.05	20.24	-52
	Minimize Methane (CH_4)	10.50	0.04	0.01	24.77	-11
	Net Carbon Footprint Strategy	2.67	0.08	0.12	17.71	-54
Swine Manure	Minimize Ammonia (NH_3)	0.70	0.99	2.71	24.05	550
	Minimize Nitrous Oxide (N_2O)	4.72	0.06	0.12	28.72	29
	Minimize Methane (CH_4)	10.39	0.79	0.00	18.56	147
	Net Carbon Footprint Strategy	2.29	0.24	0.04	10.91	-60
Poultry Manure	Minimize Ammonia (NH_3)	1.10	0.63	0.05	12.25	14
	Minimize Nitrous Oxide (N_2O)	12.09	0.00	0.13	17.54	-34
	Minimize Methane (CH_4)	18.51	0.68	0.00	29.88	7
	Net Carbon Footprint Strategy	1.93	0.24	0.04	10.91	-60

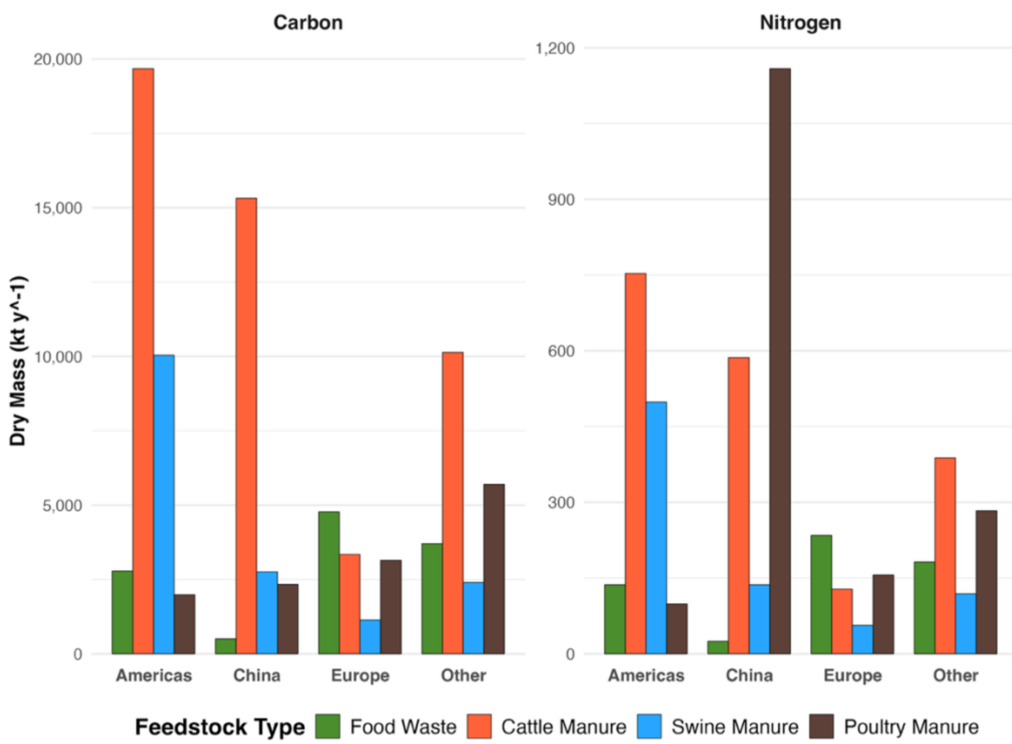
Source: *Zhang et al., 2026*

Note: *Emission metrics reflect the predicted effects of machine-learning optimal strategies derived from an analysis of 848 empirical composting trials.*

Since losses in nutrients via gas emissions are directly tied to the efficacy of compost as an organic fertilizer, achieving net GHG reductions from compost piles benefits both soil and the surrounding air quality (Nordahl et al., 2023; Esmaeilpour Moghadam et al., 2025). Globally, the compost feedstock landscape demonstrates an opportunity for improvement with respect to recycling food waste, especially in the Americas as shown in Figure 5 below.

Co-composting manure with plant waste can significantly cut GHG emissions from manure-only piles and improve the biological and physical structure of compost piles (Pérez et al., 2023; Song et al., 2026; Tanwar et al., 2026). Recent research finds that although high in nutrients, legume residues are often underutilized, resulting in significantly high opportunity costs of unrealized value-added products (Mia et al., 2025; Yu et al., 2025; Zambela et al., 2025). Integrating leguminous byproducts including peanut shells, soybean hulls, and pea pods into compost and waste-to-protein conversion channels is central to achieving a more circular nutrient bioeconomy (Maqsood et al., 2025; Dhiman et al., 2026).

Figure 5. Global Distribution of Compost Feedstock Usage Based on Nutrient Type



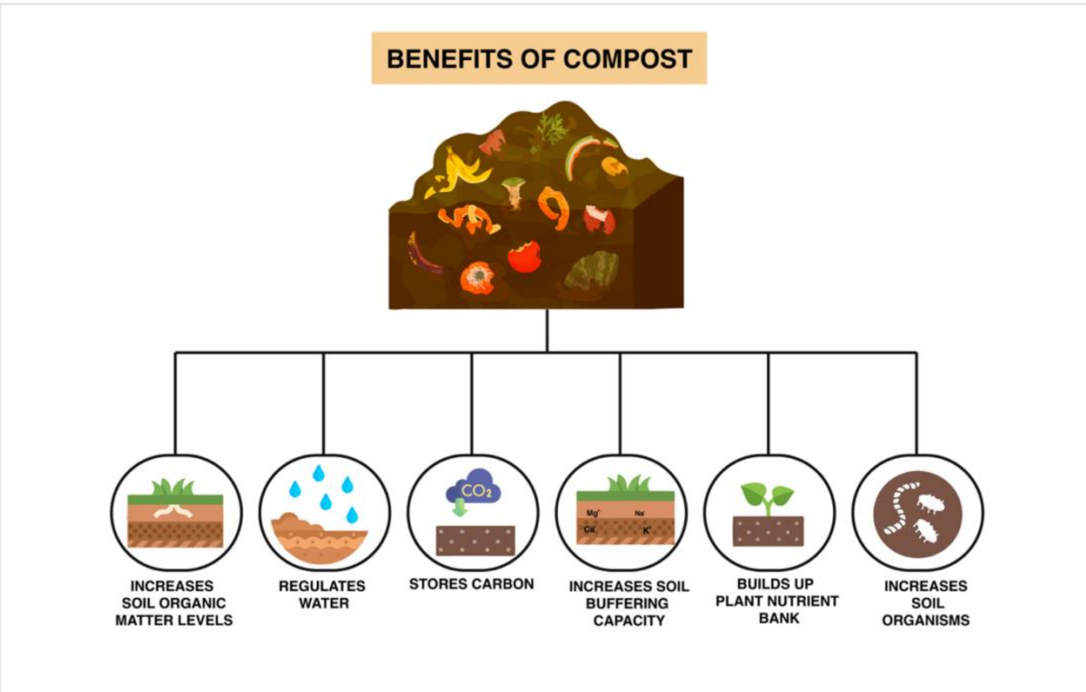
Source: *Zhang et al., 2026*

Note: *'Americas' represents the countries with available data from the two regions North and South America; 'Other' represents the available data from countries located in Asia (except China), Africa, India, and Oceania. Data is presented as the estimated dry mass of carbon and nitrogen from four types of feedstocks in kilotonnes per year (kt y^{-1}).*

In the context of alternative protein generation from waste streams, fungi are especially favorable due to their capacity to grow on low-moisture substrates (Coronel-León, 2025). Mycelia-based foods are not only more environmentally sustainable to produce relative to conventional animal-based sources such as meat and poultry, but are also highly nutritious (Quintieri et al., 2023). Given that fungi can utilize composted material as a substrate, shifting toward mycoprotein production and consumption can also bolster the transition toward a circular bioeconomy (Gebru et al., 2024; Das et al., 2026; Sahoo et al., 2026; Dhiman et al., 2024; Karp et al., 2026).

Besides waste valorization, compost has inherent value across environmental sectors as a beneficial soil amendment and fertilizer (EPA, 2025a). Moreover, metrics of soil health such as compaction, water-holding capacity, and nutrient retention illustrate some of the benefits of adding compost to agricultural soils, as shown in Figure 6.

Figure 6. Benefits of Compost Descriptive Image



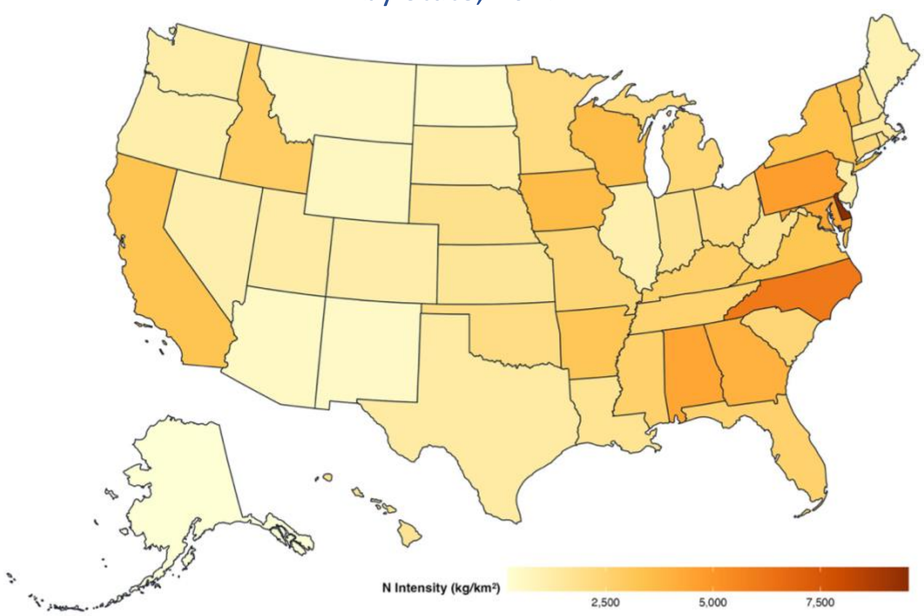
Source: *Quansah et al., 2025*

To effectively implement compost as a viable soil amendment and natural fertilizer, policymakers must balance the "Four C's" of nutrient cycling: contamination, carbon, cost, and context (Roy et al., 2025b). For instance, 'contamination' can occur if microplastics or heavy metals are present in municipal solid waste compost (Serafini et al., 2026). 'Carbon' refers to the capacity of compost to emit GHGs, meaning optimized strategies are required to make compost a net carbon sink (Zhang et al., 2026). 'Cost' concerns infrastructure investments and the price of the finished product as a synthetic fertilizer alternative (Pajura, 2024). Without organic waste diversion bans or targeted government incentives, composting operations may lag behind the rate of waste generation (Kakadellis et al., 2025; Spector et al., 2026). Lastly, 'context' encompasses the geographical, agronomic, and socio-political factors influencing the adoption and utilization of compost (Nelson et al., 2026).

B. US Nutrient Cycling: Nitrogen Dynamics

Looking at the US context, compost offers a safer and environmentally sustainable source of nutrients for crops than raw livestock manure or synthetic N fertilizers. Globally, it is estimated that livestock excrete between 80 and 131 teragrams of N annually, more than all nitrogen fertilizers (Burns et al., 2026). Meanwhile, manure represents the largest anthropogenic source of ammonia emissions in the US (EPA, 2023). As shown in Figure 7a, land-area-adjusted manure waste streams across the US showcase a wide variety of N concentrations.

Figure 7a. Land-Area-Standardized Intensity of Livestock Manure Nitrogen Generation by State, 2017



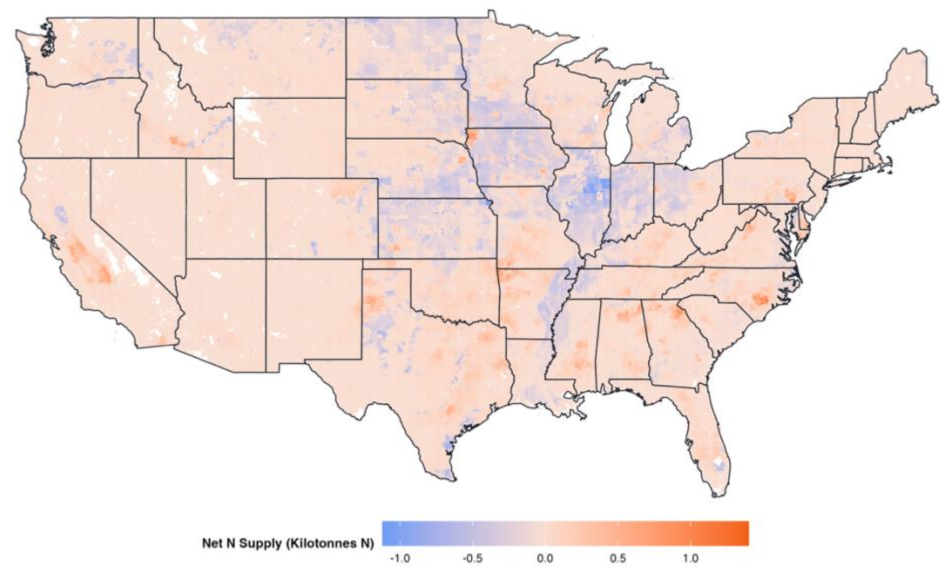
Source: *EPA, 2025b*

Note: *Chart generated using EPA data detailing the area-adjusted N waste generation from manure in 50 US states in 2017.*

Recovering N surpluses from livestock waste streams through manure processing or novel membrane-based technologies has the potential to reconcile industrial animal production with circular economic goals (Burns et al., 2026). However, geographic variations in N needs, shown in Figure 7b, demonstrate that a more decentralized, sustainable strategy is necessary to build an equitable domestic bioeconomy. As shown in Table 1 (Part IV-A), composting diverse organic waste feedstocks requires strategies informed by best management practices to ensure that emissions are controlled, especially in the case of manure (Nordahl et al., 2023).

Figure 7b below shows that the regions in a N deficit are the states that produce the most N-dependent crops, such as corn (Illinois, Iowa, and Minnesota). Research indicates that cumulative N losses generated in this region contribute to approximately $32 billion in health externalities, in part due to nitrogenous air pollutants (Goswami & Tshabalala, 2026; Esmaeilpour Moghadam, 2025; Luo et al., 2025). Livestock manure alone cannot satisfy the demand for N of monoculture corn crops, which is the primary feed grain for US livestock (USDA ERS, 2026). Co-composting manure, which has a low C:N value, with cereal agricultural residues, which have high C:N profiles, is an economically viable strategy for waste valorization (Nelson et al., 2026).

Figure 7b. Agricultural Nitrogen Surpluses and Deficits in the Contiguous US



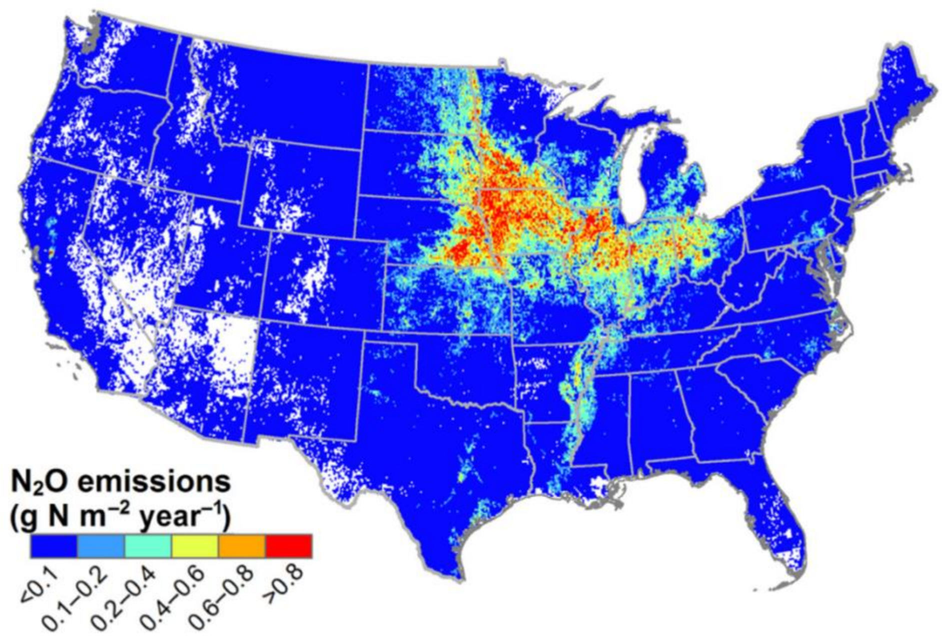
Source: Zhou et al., 2026

Note: *Net N balance is calculated as the annual organic N supply from livestock manure minus the structural vegetative N demand of major harvested crops. Baseline data is downscaled to a high-resolution, 5-arc-minute gridded geospatial framework (123,721 active cells) replicated from the modeling architecture compiled by source material. Raw values are converted to kilotonnes of nitrogen (kt/N) to evaluate local geographic variation. In contrast to the source study, this map intentionally isolates agricultural livestock waste from municipal human waste matrices to model the feasibility of decentralized, state-level circular composting policies.*

Livestock manure can thus partly offset regional N deficits by replenishing soil nutrients with compost, assuming transportation costs of livestock waste from surplus regions are manageable. With evidence indicating that many landfills across the US are soon reaching capacity, upscaling local composting efforts to divert organic waste and balance nutrient deficits is imperative for domestic agricultural resilience (Spector et al., 2026).

Data from a June 2026 report reveal that US corn acreage may decline by approximately 31 percent by 2050, presenting an opportunity for farmers to shift practices amidst changing market dynamics (S&P Global Energy, 2026). Rather than investing in expanding biofuel markets, federal and state governments can leverage this acreage contraction to resolve a key crop-derived climate liability: N_2O pollution. Soil nitrification from fertilizer overapplication drives over 90 percent of all crop-related agricultural GHG emissions, producing numerous negative health and environmental externalities (Congressional Budget Office, 2025; Luo et al., 2022). As shown in Figure 8, the Corn Belt is the highest-emitting US region—reducing corn production is thus imperative.

Figure 8. Annual Crop-Derived Nitrous Oxide Emissions Across the Contiguous US



Source: Lu et al., 2022

Note: *Average annual direct nitrous oxide (N_2O) emissions from 2010 – 2019 show that the dominant region is the Midwest.*

Despite less corn being grown for HFCS production, the 2025 marketing year still experienced record-breaking volumes of production—primarily for livestock and biofuel production. As greater corn supply will further exacerbate N_2O emissions, policies that aim to reduce consumer demand for meat and poultry must be paired with those that promote diverse agricultural systems and build up the circular economy infrastructure. Improving dietary choices, incentivizing waste valorization pathways, and upscaling composting operations can have multiple public health, environmental, and economic co-benefits.

V. One Health Policy Recommendations

A. Cap-and-Trade on Agricultural Nitrous Oxide Emissions

Despite ambitious goals for waste reduction, the US currently lacks a comprehensive regulatory policy framework for rescuing and redistributing food waste and organic material (Ryen & Babbitt, 2022). State-level policies must be supported by federal administrative assistance and more robust organic waste recycling policies (Kakadellis et al., 2025). Under a One Health framework—which analyzes the interconnectedness of human, animal, and environmental health—a circular bioeconomy can be effective in maximizing agricultural productivity (Morgan & Miller, 2026). Harnessing microorganisms across the agricultural supply chain—spanning the human gut to soil ecosystems and compost piles—is essential for optimizing One Health in the context of global food system sustainability (Couradeau et al., 2025; Rockström et al., 2025).

While state and local governments can promote composting through organic waste landfill bans and localized zoning exemptions for regional processing hubs, the federal government must supply the financial baseline to make these transitions viable. By utilizing the Farm Bill to expand funding for USDA cooperative agreements, municipal grants, and cost-sharing networks like the Environmental Quality Incentives Program, the federal government can directly support local precision-composting setups and agri-food byproduct processing infrastructure.

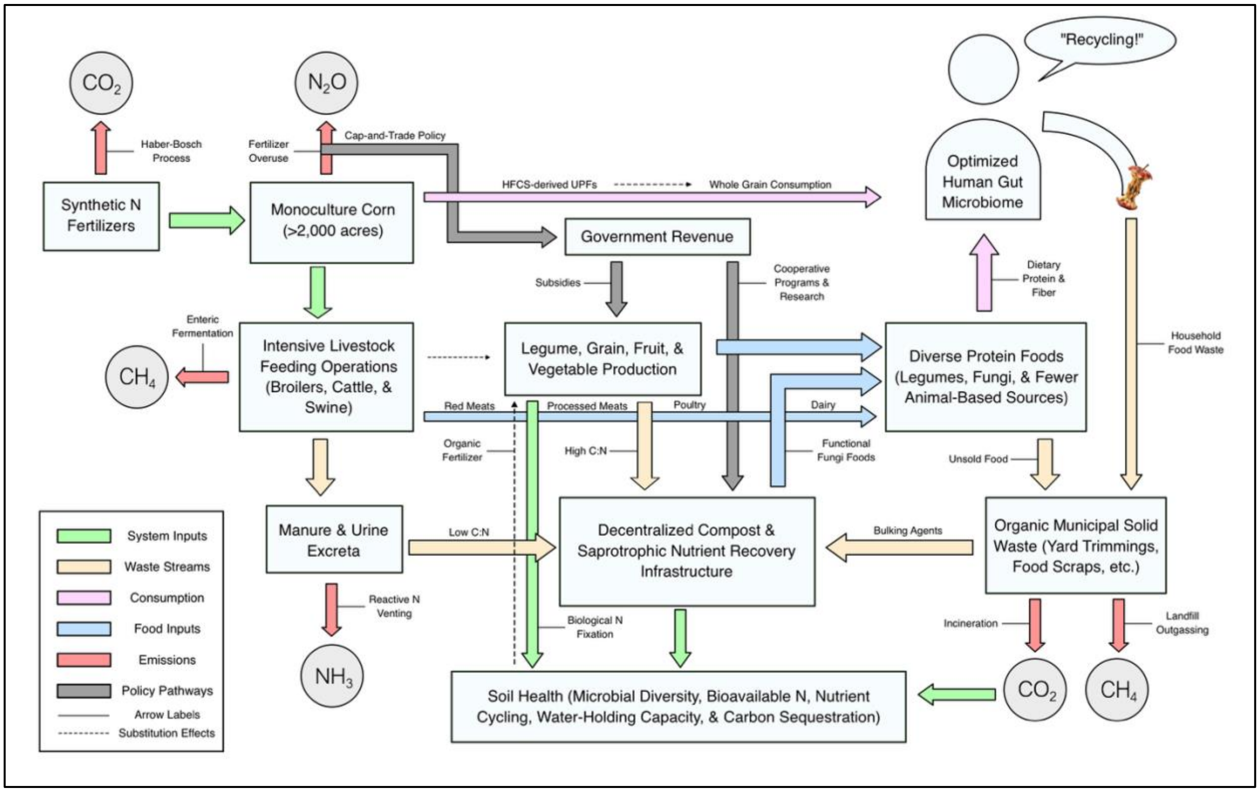
A national cap-and-trade policy that places a declining regulatory cap on agricultural N_2O emissions over the next decade could be effective in remediating upstream climate and health externalities, as shown in Figure 9. To protect independent family farms from the financial squeeze of consolidated input costs, the cap could apply to large industrial monoculture producers operating above a 2,000-acre threshold. Independent, diversified growers below this threshold would be exempt from penalties, whereas large-scale monoculture corn operations—the primary drivers of N_2O pollution—would consistently exceed the cap and face necessary fiscal pressures to diversify.

There are two notable circular effects of a national N_2O-based cap-and-trade policy:

1. Upscaling compost and fungal nutrient recovery infrastructure can recycle food and agricultural waste while generating alternative sources of protein (Hoxha et al., 2026).
2. Investing in legume and diverse plant food production can strengthen soil health while generating useful feedstocks for composting facilities via high C:N agricultural residues (primarily from cereal and legume crops). This creates a balanced organic fertilizer that can substitute for fertilizer synthesized through the fossil fuel-dependent Haber-Bosch process.

At the same time, research funding is essential to promote best management practices and awareness for both households and regional multi-input facilities.

Figure 9. Cap-and-Trade Policy Mechanism Flow Chart



Note: *Arrow sizes and box areas do not represent the proportions of real volumes of resources flowing throughout the US food system. C = carbon, N = nitrogen, CO_2 = carbon dioxide, CH_4 = methane, NH_3 = ammonia, N_2O = nitrous oxide, HFCS = high fructose corn syrup, UPFs = ultra-processed foods.*

B. Life Cycle Assessment Value-Added Taxes

Shifting the dominant source of protein away from meat and poultry and toward plants and fungi optimizes human, animal, and ecological health under a One Health circular economy framework (Komati et al., 2025; Bueno de Mesquita et al., 2026; Firincă et al., 2026). If corn production drives N_2O emissions and livestock manure drives NH_3 emissions, then a front-end shift in agricultural diversification toward N-fixing legume crops can induce better back-end waste management strategies, creating a more circular nutrient bioeconomy.

To elicit such supply-side changes, protein food consumption habits must change. Behavioral economics demonstrates that individuals frequently rely on default options and environmental cues that require the least cognitive effort (McCart et al., 2026). While redesigning this choice architecture—such as establishing healthy defaults, introducing environmental nudges, and lowering the friction costs associated with sustainable choices—can predictably influence population behaviors, these structural shifts are most effective when paired with direct fiscal interventions (Hosni et al., 2025).

The implementation of life cycle assessment-based value-added taxes (LCA-VATs) on retail-level processed food products is a robust fiscal and behavioral strategy to internalize the unpriced environmental and nutritional externalities of intensive livestock production and processed food consumption. Using environmental and economic data, state legislatures can tailor the taxation threshold based on the estimated emissions of the food products.

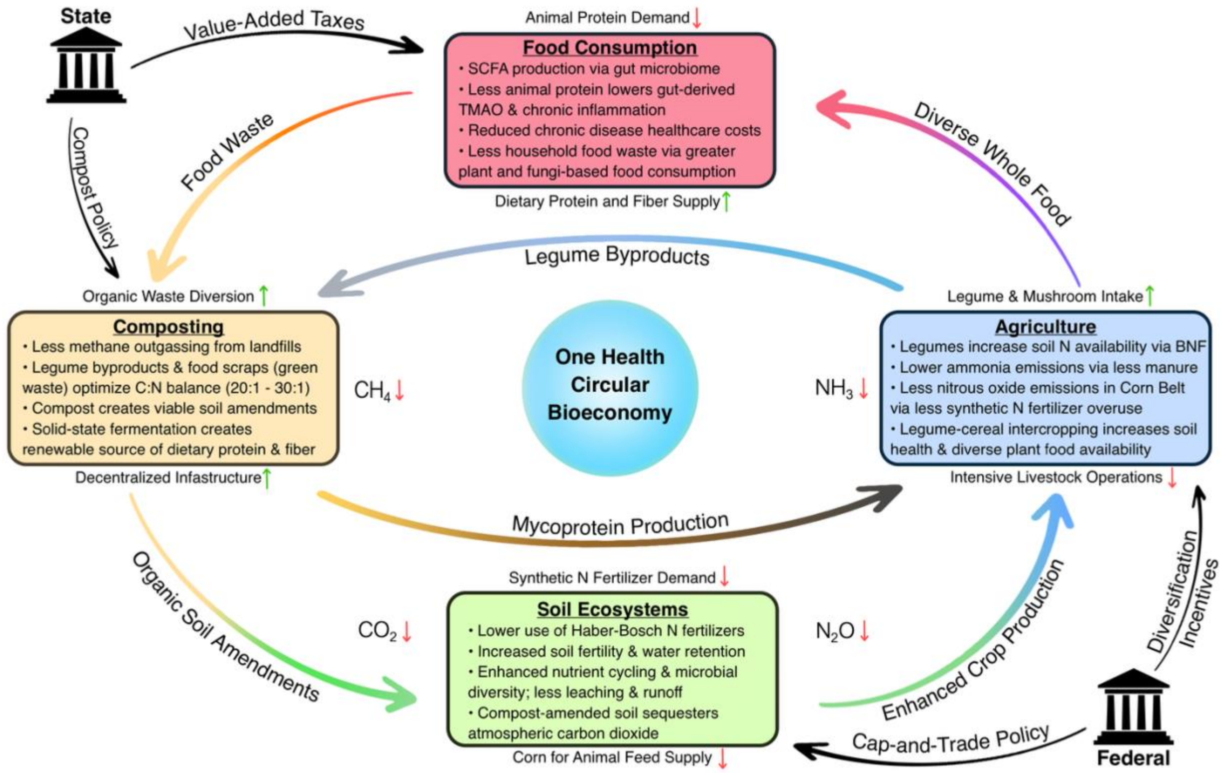
This framework scales a product's tax tier directly to the aggregate life cycle GHG emissions associated with a specific processed food's production cycle. By targeting key pollutants like N_2O and NH_3, resource-intensive protein sources—like red and processed meat products—and ultra-processed foods (foods high in HFCS) fall into the highest tax brackets due to their heavy reliance on monoculture corn. Conversely, by exempting localized producers and whole food categories, the policy ensures that foods yielding a net-neutral or net-negative impact on the biosphere remain entirely tax-free.

Intuitively, such a mechanism aligns macro-level agroeconomic circularity with domestic consumer behavior. However, modeling evidence suggests that while effective at reducing GHG emissions from food purchases, VATs can be financially regressive (Tiboldo et al., 2026). Because low-income households spend a significantly larger proportion of their income on food, the tax burden falls disproportionately on them. Without concurrent support, this economic strain risks negatively impacting the nutritional outcomes of vulnerable populations by pricing them out of high-quality proteins.

To offset these regressive effects, revenue generated from an LCA-VAT must be recycled to subsidize minimally processed foods—a strategy that aligns economic logic with health equity goals to result in net financial gains and improved nutritional outcomes for low-income households (Valizadeh & Ng, 2024). Though, without careful targeting, this approach may still disproportionately benefit higher-income groups who are better positioned to take advantage of the lower cost of plant protein alternatives (Al-Masbhi et al., 2026).

Redirecting revenues to address the nutritional and economic needs of low-income consumers, such as by distributing produce vouchers or establishing food donation pathways, is necessary to ensure that food taxation policies are equitable. Overall, leveraging taxes and subsidies to encourage healthier dietary choices can be an equitable, economically prudent, and viable strategy for improving health outcomes and fostering environmental sustainability, if implemented judiciously (Rub, 2026). The LCA-VAT is one of many fiscal approaches that can drive progress toward creating a One Health circular bioeconomy, as shown in Figure 10.

Figure 10. Policy Interventions for a One Health Circular Bioeconomy [Abstract]



***Note:** C:N = carbon-to-nitrogen, CO_2 = carbon dioxide, CH_4 = methane, NH_3 = ammonia, N_2O = nitrous oxide, BNF = biological nitrogen fixation, SCFA = short-chain fatty acids, TMAO = trimethylamine-N-oxide.*

Emissions can be further curtailed by a national protein transition. Methane emissions from produce waste dumping in landfills and carbon dioxide emissions from incineration are both substantially reduced by increasing the demand for plant foods. At the same time, upscaling decentralized composting allows for market innovation in the development of organic waste valorization pathways, creating protein foods and bio-based materials (Bhardwaj et al., 2025; Machado et al., 2026). Under a One Health paradigm, advancing evidence-based food policy in tandem with compost incentives can strengthen the productivity of multiple economic sectors.

VI. Conclusion

- By shifting from meat consumption toward diverse, sustainable sources of protein—namely, legumes and mushrooms—the human gut microbiome produces more SCFAs and less TMAO, reducing the burden of chronic disease and subsequent healthcare expenditures.
- Shifting national dietary protein demand would lower the need for intensive livestock operations, resulting in lower N_2O emissions from the US Corn Belt given the substantial

input of synthetic N fertilizers in the region, as well as less NH_3 emissions from livestock manure.

- The integration of legume byproducts and hardy plant food waste into composting operations promotes the generation of viable soil amendments and provides nutritious substrates to produce mycoprotein.
- Inputting composted agri-food products and consumer-derived food scraps into soil ecosystems promotes microbial diversity and crop nutrition, creating a net carbon sink while advancing the sustainable production of cereal grains and legumes.

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