Peertechz

Journal of Food Science and Nutrition Therapy

ISSN: 2641-3043 Journal DOI: https://dx.doi.org/10.17352/jfsnt

Review Article

Addressing the Impact of Pesticides on the Food Chain for Human and Ecosystem Health

Felix Kwabena Donkor*

Department of Geography Education, University of Education-Winneba, Winneba-Ghana

Submitted : 09 March, 2026
Accepted : 29 August, 2026
Published : 31 August, 2026

***Corresponding author:** Felix Kwabena Donkor, Department of Geography Education, University of Education-Winneba, Winneba, Ghana,
E-mail: felixdonkor2002@yahoo.co.uk

Keywords: Food security; Ecosystem health; Wellbeing; Pesticides; Food chain

Abstract

The SDGs of "zero hunger" (SDG 2) as well as "good health and wellbeing" (SDG 3) are two cross-cutting themes that are vital for humanity to thrive. However, a confluence of factors such as rapid population growth, urbanisation, and poor land use/ agricultural practices has compromised efforts at these noble goals. As the timeline for attaining the SDGs draws closer, it has become urgent to find effective measures that will address some of the core challenges therein and advance these SDGs. One such pressing issue is the abuse of pesticide use. This study adopts qualitative methods involving the systematic study of literature to investigate how the use of pesticides affects the food chain with implications for ecosystem and human health. The study shows that pesticide contamination of food chains is a significant ecological and public health concern because these synthetic compounds do not remain confined to their target application sites. Instead, they disperse through runoff, atmospheric drift, and leaching into soils and water bodies, where they enter complex trophic networks. This initiates a cascade of trophic transfer that can propagate contamination upward through the food chain. Targeted public sensitisation, enforcement of laws, capacity building and a shift towards more organic approaches will help surmount this challenge with implications for global food security, ecosystem health and attainment of the SDGs 2 and 3.

Introduction

The sustainable development goals

The Sustainable Development Goals (SDGs) were agreed on by all United Nations countries in 2015 and are the biggest global plan for development so far [1]. They include 17 goals, 169 targets, and 232 indicators, and they took over from the Millennium Development Goals (MDGs) with a much wider purpose. While the MDGs mostly aimed to reduce poverty in poorer countries, the SDGs apply to every country and cover three main parts of development: the economy, society, and the environment [2].

The transformative ambition of the sdgs

Many authors emphasize the SDGs' bold, transformative goals. The agenda is praised for linking issues together and treating them as inseparable, since poverty, inequality, environmental damage, and conflict are all connected and need broad, joined-up solutions [3]. The idea of "leaving no one behind" shows a clear move to tackle deep inequalities and to reach the most excluded groups, such as women, indigenous peoples, and people with disabilities [4]. The SDGs also recognize Earth's environmental limits, putting sustainability at the center with specific goals on climate action, oceans, and land ecosystems, rather than treating the environment as a side issue [5]. Researchers note that the SDGs were shaped through wide participation; civil society, universities, businesses, and local governments all contributed, which contrasts with older, top-down development approaches [6].

Implementation challenges: From ambition to action

Although the SDGs are widely praised, much research points out a gap between their goals and real-world progress. One big problem is how complicated the framework is. The 169 targets create coordination challenges and possible trade-offs; for example, pursuing economic growth (Goal 8) can clash with climate action (Goal 13) or responsible consumption (Goal

Citation: Donkor FK. Addressing the Impact of Pesticides on the Food Chain for Human and Ecosystem Health. Food Sci Nutr The. 2026;12(1):9-16. Available from: https://dx.doi.org/10.17352/jfsnt.000060

12) [3]. Scholars say the lack of clear order or priorities leaves governments, especially in low-resource countries, struggling to act [7]. The SDGs are voluntary and depend on national commitment rather than binding rules, which critics argue provides no strong enforcement. As a result, many countries have national SDG plans, but actual implementation varies widely, with weaknesses in data, monitoring, and funding [8]. Current forecasts indicate that, if things continue as they are, only some SDG targets will be achieved by 2030, and the COVID-19 pandemic has made meeting them harder [9].

The focus on public-private partnerships and "innovative finance" is seen by some as a way for corporations to shape development while avoiding responsibility [7]. Also, researchers warn that treating environmental issues as separate "goals" instead of limits that affect all economic actions weakens the push for urgent ecological change [10]. Finally, the targets are criticized as too technical and focused on measurable indicators, favoring what can be counted over what truly matters for people's well-being and the health of the planet [11].

Overall, the SDGs are widely viewed as a major achievement in global cooperation, reflecting an unusual agreement on common human and environmental goals. However, researchers agree that the SDGs will not bring big change unless there are major reforms in how decisions are made, how projects are financed, and the political commitment to act. With 2030 nearing, the SDGs should not be seen as a final plan but as a continuing space for debate, bargaining, and future opportunities.

One area where this contestation and negotiation is animated is in the context of SDG 2 under the broader theme of "zero hunger". SDG 2 is premised on the notion that sustaining the world should not result in wanton destruction of the environment [12]. This is more so as agriculture is a major cause of environmental degradation and poor land use practices translate into dire consequences for biodiversity and the climate. Hence, healthy diets premised on sustainable food systems have gained policy focus as the global population increases, with increased pressures on the ecosystem [12]. As the global population is estimated to pass 10 billion in the second half of the century, eliminating hunger has become an ever-pressing issue. This makes it necessary to address farming or land use practices that compromise the critical ecosystem services that support sustainable farming or agriculture.

Ecosystem services and their importance

The idea of ecosystem services is now a leading way to look at how human well-being connects to nature. Made widely known by the Millennium Ecosystem Assessment [13], ecosystem services are defined as the direct and indirect benefits people get from nature. This approach has transformed green policy, conservation work, and sustainability goals by turning natural processes into clear benefits for society [14]. Experts group these services into four connected types: provisioning, regulating, supporting, and cultural, with each playing a vital role in keeping people alive and helping communities thrive.

Provisioning Services: The Physical Basics of Survival

Provisioning services are the clearest and most direct benefits nature provides. These consist of food, clean water, wood, fabrics, and natural medicines [13]. Research clearly shows that more than 1.6 billion people worldwide rely on forests to make a living, while wild fish supply the main source of protein for nearly 3 billion people [15]. Across Africa, these services are especially vital, as local communities depend on wild plants, animals, and natural remedies for daily meals and basic medicine [16]. Still, experts frequently warn that taking too much from nature, pushed by growing populations and commercial demand, endangers the future of these essential goods, making strong protection rules necessary [17].

Regulating Services: The Hidden Support for Stability

Regulating services are often called the "unsung heroes" of nature's systems. They cover climate control, flood protection, water cleaning, crop pollination, and disease control [18]. Research strongly shows that traditional economic systems fail to value these services properly, causing them to break down [19]. For example, wetlands are estimated to offer flood safety worth over $23 billion each year in the United States alone, yet people keep draining them for new buildings [20]. Likewise, insect pollination, mostly by bees, adds an estimated $235 to $577 billion a year to global farming, showing how natural controls support food supplies and steady economies [21]. Experts stress that losing these regulating services directly increases climate risks, making their protection a crucial step for staying safe [22].

Supporting Services: The Base for All Natural Systems

Supporting services are the background processes that allow every other natural service to work. These involve nutrient recycling, soil creation, plant growth, and oxygen release through photosynthesis [13]. Research stresses that supporting services take the longest to recover from damage because they work over vast periods of time [23]. Soil creation, for instance, happens at a speed of mere millimeters every hundred years, yet global soil loss is currently 10 to 40 times faster than it can form, marking a major but frequently overlooked problem [24]. Experts regularly point out that conservation plans must put supporting services first because breaking them causes provisioning and regulating services to fail as well [25].

Cultural Services: The Non-Physical Aspects of Value

Cultural services cover the non-physical gifts that nature offers, such as spiritual growth, personal learning, fun activities, and scenic beauty [13]. Studies increasingly view these gifts as vital to human identity and mental health, especially for native groups whose daily traditions are closely tied to particular lands [26]. In South Africa, for instance, the cultural heritage of local communities is bound to sacred grounds and traditional lands, making these services a key piece of community unity and strength [27]. Still, cultural services are the hardest to measure with money, which causes decision-makers to regularly leave them out of official plans [28].

Citation: Donkor FK. Addressing the Impact of Pesticides on the Food Chain for Human and Ecosystem Health. Food Sci Nutr The. 2026;12(1):9-16. Available from: https://dx.doi.org/10.17352/jfsnt.000060

Economic valuation and policy integration

A major part of the research focuses on the challenge of putting a value on ecosystem services. Costanza et al. [14] famously estimated the total value of global ecosystem services at around $33 trillion every year, which was almost double the world's economy at the time. Though researchers debated this number, later studies improved the methods, stressing that measuring value is not about turning nature into a product, but about showing the unseen ways ecosystems help human life [18]. The TEEB (The Economics of Ecosystems and Biodiversity) system played a key role in bringing these ecosystem values into national financial reports, steering policies like REDD+ (Reducing Emissions from Deforestation and Forest Degradation) and nature protection projects [19]. As the world confronts biodiversity loss and climate change, the ecosystem services paradigm offers a powerful lens for aligning human activity with ecological integrity. The soil ecosystem is one area where such confrontation of biodiversity loss and climate change deserves attention.

The soil ecosystem and its importance

Soil is much more than mere dirt hosting plants; it is an active, living system that stands as one of the most diverse and vital parts of land life on Earth. Formed as the thin layer of ground that feeds life, soil builds up through long-term connections between rocks, climate, land shape, living things, and time [29]. Research increasingly views soil not just as ground material, but as a "living system" that provides essential ecosystem benefits, fuels world food supplies, balances climate, and protects wildlife [30].

The soil is a massive center for diverse life. Just one gram of healthy soil can hold up to 10 billion microscopic organisms, including thousands of types of bacteria, fungi, single-celled life, and tiny worms, along with larger creatures like earthworms, ants, and termites [31]. This huge variety of life is not just there by chance; it is the main engine that keeps soil working. Studies stress that soil creatures handle almost every natural cycle, including carbon, nitrogen, phosphorus, and sulfur, making them essential for nature's growth [32]. Mycorrhizal fungi, for instance, partner up with over 80% of land plants, helping them take in water and nutrients in trade for plant sugars [33]. Experts increasingly state that soil life forms the base for all land life, and losing it leads to a breakdown across the whole ecosystem [34].

The multifunctional importance of soil ecosystems

Research consistently highlights soil as the cornerstone of many natural services, which are usually grouped under the Millennium Ecosystem Assessment [13] setup. First, soil is basic to food supplies through its physical goods. Over 95% of world food relies, directly or indirectly, on soil, making it the main base for farming systems [15]. Soil quality, set by organic matter, available nutrients, and texture, directly affects crop amounts and food quality [24].

Second, soil offers vital control services, especially in slowing down climate change. Soils make up the largest land store for carbon, holding around 2,500 gigatons of carbon, which is more than the air and all plants put together [35]. Studies stress that storing carbon in soil through smart land care gives a practical way to balance out human-made gas pollution [36]. On top of that, soil manages water flow by soaking up, holding, and cleaning water, with swamps and woods playing major roles in stopping floods and refilling underground water [37].

Third, soil supports nutrient cycles and provides living space. Earthworms and other soil life physically reshape the soil, building open spaces that boost air flow, water drainage, and root growth, a process often called "ecosystem engineering" [38]. Research also points out soil's ability to break down pollutants and clean up toxins, as micro-bugs work together to dissolve chemical waste and act as a natural filter [39].

Threats to soil ecosystems: A growing crisis

A large amount of research tracks the alarming speeds of soil damage around the world. The FAO [15] estimates that one-third of global soils are already damaged by erosion, compaction, salt buildup, pollution, and the loss of organic material. Soil erosion on its own causes the loss of 24 billion tons of rich topsoil every year, cutting farming output by an estimated $400 billion annually [24]. Heavy farming, cutting down forests, overgrazing, and expanding towns are listed as main causes, with the Global Assessment of Soil Biodiversity [40] warning that soil life faces unmatched risks.

Studies warn that soil damage is both a cause and a result of climate change, creating a dangerous cycle that weakens natural stability [30]. In Africa in particular, research points out that losing nutrients, rising acidity, and dropping organic matter are heavily limiting crop harvests and food supplies [41]. Even with these worrying trends, experts regularly point out that soil is still ignored in official rules, lacking the focus given to woods, oceans, or wildlife [42]. Soil is a core living system whose health is directly bound to human well-being, food safety, and a steady climate. Despite the critical importance of the soil ecosystem, increasing poor land use and agricultural practices continue to degrade the soil, which undermines efforts at enhancing agricultural productivity to boost food security for the global populace. This has become an urgent issue as the timeline for attaining the SDGs draws to a close in the final decade of action. This study investigates the impact of pesticide use on the food chain for human and ecosystem health. It contributes to the debate on advancing sustainable land use practices that reinforce food security and health of the ecosystem.

Methodology

This systematic literature review was facilitated with a compilation of evidence from multiple databases including Science Direct and Google Scholar. Searches revolved around keywords such as: pesticides, food chain, human health and wellbeing, pesticide impact on humans, pesticides and soil biosphere, pesticide effects on the ecosystem, inter alia. Through the help of Boolean operators, tailored phrases were employed to facilitate the search for relevant data. Articles that were produced in English and were within a 5 year frame were selected once they aligned with the rationale of this study.

Discussion

The 2030 Agenda for Sustainable Development, of the United Nations Member States in 2015, offers a common blueprint for safeguarding the peace and prosperity of humanity and the planet for the present as well as posterity [43]. The Sustainable Development Goals (SDGs) revolve around 17 cardinal themes, of which SDG 3 is premised on the goal to "Ensure healthy lives and promote well-being for all at all ages" [43]. The health of the ecosystem is intricately linked to the health of society, which makes it necessary to interrogate actions that compromise the health of the ecosystem. Khosravi Mashizi and Sharafatmandrad [44] argue that the connections underpinning human health and ecosystems are intricate, dynamic, and political. Moreover, ecosystems have sustained humans with indispensable services including food, water, shelter, and medicine. In addition, they mediate the transmission of several diseases [45,46]. It has been observed that anthropogenic activities have transformed and continue to change the biological integrity of Earth's ecosystem. The increased pressure has led to significant degradation of the ensuing ecosystem services.

The use of pesticides is one such anthropogenic action that directly affects the health of the ecosystem [47]. In general, pesticides are employed to eradicate undesirable plants. An upsurge in the use of pesticides has been linked to the need to increase food production to a growing human population. This agricultural intensification has led to a significant increase in the use of options such as weedicides [47]. However, their unregulated use leads to excesses that cause bioaccumulation in the environment, which makes them a major contaminant.

The use of weedicides has become widespread worldwide, whilst accumulation transfers have been observed through species via the food chain and ultimately humans. Regarding human health, weedicides tend to bioaccumulate in human cell membranes and undermine proper bodily functions. Furthermore, the excessive use of weedicides can lead to residues in plants and soils, raise toxic levels in crops, result in herbicide-resistant weeds, and harm non-target organisms [48]. Environmental contamination ensuing from weedicide usage is attributed to the leaching of weedicides into the soil and water systems. This affects soil health as beneficial microorganisms that enhance nutrient cycling and soil structure are killed. In the long run, soil fertility is destroyed whilst soil erosion escalates [49].

1. Impact of pesticides on soil microflora

Soil microflora comprising bacteria, fungi, archaea, and other microorganisms constitutes the biological engine of terrestrial ecosystems, driving essential processes such as nutrient cycling, organic matter decomposition, soil structure formation, and carbon sequestration. However, the extensive application of pesticides in modern agriculture represents a significant anthropogenic pressure on these non-target organisms [50]. Only a fraction of sprayed pesticides effectively reaches target pests, while the remainder accumulates in the soil as persistent residues, raising serious environmental concerns.

A substantial body of research documents that pesticides, including insecticides, fungicides, and herbicides, exert diverse detrimental effects on soil microorganisms by decreasing microbial biomass, altering enzyme activity, and disrupting nutrient cycling [51]. Evidence from both field experiments and meta-analyses indicates that pesticide exposure leads to measurable changes in bacterial, fungal, and protist communities, with long-term disruptions in soil functionality. Specific functional groups, particularly nitrogen-transforming microorganisms such as ammonia-oxidizing bacteria and archaea, are among the most sensitive to such disturbances.

The impacts are not limited to biomass reduction. Pesticides degrade microbial cellular structures, disrupt biochemical reactions, and hinder beneficial biological activities, including the critical relationships between plants and their microbial symbionts. Fungicides, which are specifically designed to control fungal pathogens, can inadvertently affect non-target beneficial soil microorganisms, with some compounds retaining high concentrations in soil for extended periods [51]. The effects also vary by pesticide type and are context-dependent, influenced by soil chemical and physical properties, management practices, and the composition of the microbial community itself.

Functional vs. structural changes and the challenge of detection

A critical insight emerging from the literature is the distinction between functional and structural changes in microbial communities. Recent studies reveal that apparent stability in microbial activity does not necessarily indicate ecological resilience, as significant changes in community structure and interaction networks may persist beneath the surface. This phenomenon is partly explained by functional redundancy, where multiple species share similar ecological roles. Consequently, while a pesticide may not immediately affect a specific soil function like nitrogen fixation, it can still alter the abundance of key microbial species that perform that function, creating latent risks.

In our contemporary society, advances in molecular and omics-based technologies, including 16S rRNA sequencing, metagenomics, and transcriptomics, have significantly enhanced the capacity to assess pesticide impacts at high resolution, enabling the identification of sensitive microbial taxa and functional gene expression patterns. These techniques have also illuminated the potential for bioremediation; specific bacteria (e.g., *Pseudomonas*, *Bacillus*, *Rhodococcus*) and fungi (*Aspergillus*, *Penicillium*) can degrade pesticides using enzymes encoded by genes. However, degradation effectiveness is strongly influenced by pH, temperature, organic matter, and soil texture.

Citation: Donkor FK. Addressing the Impact of Pesticides on the Food Chain for Human and Ecosystem Health. Food Sci Nutr The. 2026;12(1):9-16. Available from: https://dx.doi.org/10.17352/jfsnt.000060

Pesticides significantly alter soil microbial communities through both structural shifts and functional disruptions [50]. The challenge for sustainable agriculture lies in moving beyond single-response metrics to integrative monitoring strategies that capture cumulative pesticide pressures. Sustainable practices such as compost addition, biofertilizers, and microbial consortia show promise in mitigating pesticide-driven losses of microbial diversity. Future research must prioritize understanding pesticide-microbiome interactions in understudied contexts, particularly in tropical regions, and develop standardized frameworks for translating microbial bioindicator research into practical soil health monitoring tools.

Impact of pesticides on soil microfauna

Soil microfauna and mesofauna encompassing nematodes, protists, springtails (Collembola), mites (Acari), and earthworms constitute a significant fraction of global biodiversity and play indispensable roles in maintaining soil ecosystem functions. These organisms are fundamental to decomposition, nutrient cycling, soil structure formation, and the regulation of pest populations [52]. However, intensive agricultural practices involving widespread pesticide application exert substantial pressure on these non-target communities. This literature review synthesizes current evidence on the impacts of pesticides on soil faunal communities and their functional consequences.

Pesticide effects are stronger on soil fauna *diversity* than on abundance, indicating that species richness and community composition are particularly vulnerable.

The most detrimental scenarios identified involve multiple substances, broad-spectrum products, and insecticides, which consistently decreased soil fauna diversity even when applied at recommended rates [52].

Studies on microarthropod communities in agricultural settings reveal that sequential applications of pesticides can exert additive or synergistic effects not observable when assessing compounds individually, raising concerns about the ubiquity of pesticide mixtures in agricultural soils.

Responses across different faunal groups

Pesticide impacts vary considerably among faunal groups. Collembolan (springtails) appear particularly sensitive to insecticides, with significant abundance reductions documented following exposure. In contrast, some studies report that mites (Acari) show comparatively lower sensitivity to certain compounds such as neonicotinoids, suggesting organism-dependent responses. Earthworms, vital for soil structure and nutrient cycling, experience adverse effects including reduced cocoon production and survival, with evidence that even sublethal doses significantly impair reproductive capacity.

Furthermore, emerging research highlights that pesticide exposure influences the gut microbiomes of soil invertebrates. In *Amynthas gracilis* earthworms, soils with high pesticide contamination correlated with structural shifts in intestinal microbial communities, potentially affecting organism health and ecological functionality.

Policy implications and future directions

The evidence that pesticide use has significant non-target effects on soil biodiversity provides crucial support for policies aimed at reducing pesticide reliance in agriculture. The detrimental effects of multiple substances are particularly concerning given realistic agricultural scenarios combining several pesticides over a crop season suggest that future regulatory frameworks must better capture long-term consequences under realistic field conditions [53]. Future research priorities include addressing geographical and taxonomic biases, investigating indirect effects mediated by species interactions, and exploring how interactive effects of multiple stressors and climate change affect soil faunal communities.

The impact of pesticides on the food chain

Pesticide contamination of food chains is a significant ecological and public health concern because these synthetic compounds do not remain confined to their target application sites. Instead, they disperse through runoff, atmospheric drift, and leaching into soils and water bodies, where they enter complex trophic networks.

Once released into the environment, pesticides infiltrate food webs through multiple pathways [54]. Aquatic organisms absorb contaminants directly from water, ingest contaminated sediment particles, or consume contaminated prey. In terrestrial systems, arthropods represent a critical entry point for pesticide transfer, as they constitute approximately 80% of all animal species and serve as primary food sources for many predators. Research demonstrates that herbivorous arthropods feeding on treated plants rapidly take up pesticide residues, and these contaminated organisms, while often surviving with reduced fitness, are subsequently consumed by predators such as spiders, coleopterans, and birds. This initiates a cascade of trophic transfer that can propagate contamination upward through the food chain.

Recent field evidence has revealed unexpected pathways of pesticide movement. Flood-borne pesticides can transfer from riparian soils to stinging nettle plants and subsequently bioaccumulate in aphids feeding on them, confirming that flood events can introduce contaminants into terrestrial food webs. This aquatic-to-terrestrial pathway highlights the interconnected nature of food webs and the far-reaching consequences of pesticide contamination.

Bioaccumulation and biomagnification: Complex patterns

Understanding how pesticides behave across trophic levels requires distinguishing between bioaccumulation (storage in tissues over time) and biomagnification (increasing concentrations with each trophic level). Historical evidence from DDT studies demonstrated clear biomagnification, with concentrations increasing dramatically up the food chain.

Citation: Donkor FK. Addressing the Impact of Pesticides on the Food Chain for Human and Ecosystem Health. Food Sci Nutr The. 2026;12(1):9-16. Available from: https://dx.doi.org/10.17352/jfsnt.000060

The chemical properties and toxicokinetics of pesticides, combined with the resistance and detoxification abilities of organisms, ultimately determine bioaccumulation potential. Persistent organochlorines such as DDT, dieldrin, and HCHs bind to organic matter and persist for decades, with residues still detected in soils and milk despite being banned in many countries. Conversely, modern neonicotinoids, while more hydrophilic and theoretically less prone to biomagnification, have demonstrated unexpected trophic transfer capabilities that challenge traditional bioaccumulation models.

Ecosystem and human health consequences

The ecological consequences of pesticide trophic transfer are profound [55]. Arthropod declines in some regions are partially attributed to pesticide exposure through both direct and food chain-mediated routes. As predators consume contaminated prey, sublethal effects accumulate, impairing reproduction, feeding efficiency, and fitness while potentially inducing lethal outcomes in top predators.

Human exposure occurs primarily through dietary intake of residues. Pesticides traverse food chains through multiple pathways, with bioaccumulation patterns varying considerably based on chemical properties, organism metabolism, and food web structure. The aquatic-to-terrestrial transfer route and the potential for trophic transfer of modern pesticides challenge traditional assumptions about contamination pathways. Future research must prioritise understanding pesticide mixtures, improving detection methods for low concentrations in small organisms, and quantifying how trophic structure influences contaminant transfer. As international food trade drives global pesticide use, stronger monitoring and regulation, particularly in the Global South, remain essential to mitigate risks to ecosystem integrity and human health.

The impact of pesticides on human well-being

Pesticides, while vital for agricultural productivity, represent a pervasive threat to human well-being that extends far beyond the farm. They enter the human body through direct contact, inhalation, or by consuming contaminated food and water, and are increasingly recognized as primary drivers of a wide range of non-communicable diseases (Ahmad et al., 2024). The mechanisms of harm are diverse, encompassing acute toxicity from high-dose exposure and, more insidiously, chronic conditions that arise from the accumulation of residues over a lifetime.

Direct and severe neurological impacts

The link between pesticide exposure and neurological damage is one of the most extensively documented and alarming health consequences. Organophosphates and carbamates, in particular, are highly toxic as they directly affect the central nervous system. The mental health toll is also significant [55]. A recent cross-sectional study of adults living near industrial pig farming facilities found measurable associations between environmental pesticide residues and poorer mental health outcomes. Specifically, chlorpyrifos detected in well water was linked to more depressive symptoms and lower mental quality of life, while cypermethrin was associated with greater psychological distress. This suggests that even non-occupational, environmental exposure can profoundly impact psychological well-being.

Endocrine disruption and reproductive harm

Pesticides are potent endocrine disruptors, interfering with hormonal systems and leading to severe reproductive and developmental health issues [56]. Studies have reported reduced fertility among agricultural workers and a higher prevalence of male infertility in regions with intensive pesticide use. The impacts are not limited to adults; they threaten the health of future generations [57-65].

Some studies indicate that women exposed to organophosphates, pyrethroids, and carbamates even *before* becoming pregnant were more likely to give birth to newborns with lower Apgar scores, a key indicator of neurological health that correlates with long-term childhood outcomes. This critical research identifies the preconception period as a sensitive window of exposure, underscoring that the threat to human well-being begins before conception itself.

Heightened vulnerabilities in children

Children are uniquely susceptible to the effects of pesticides. Their developing organ systems, higher metabolic rate, and greater exposure relative to their body weight make them particularly vulnerable to both the short and long-term consequences. A narrative review of the literature concluded that pesticide exposure is associated with an increased risk of neurological, endocrinological, and immunological diseases, as well as childhood cancers. Further evidence shows that children exposed to pesticides have more than double the risk of developing asthma symptoms, and that proximity to agricultural spraying is linked to increased respiratory, dermatologic, and systemic symptoms in children.

Conclusion

Pesticides are a significant risk factor for human well-being, impacting neurological health, mental health, reproductive capacity, and child development. The pervasive nature of exposure, combined with the severity and persistence of the associated health conditions, calls for urgent regulatory reform and a global shift towards less chemically dependent agricultural practices.

References

1. United Nations. Transforming our world: the 2030 Agenda for Sustainable Development. New York (NY): United Nations; 2015.
2. Sachs JD. The age of sustainable development. New York (NY): Columbia University Press; 2015.
3. Nilsson M, Griggs D, Visbeck M. Policy: map the interactions between Sustainable Development Goals. Nature. 2016;534(7607):320-2. Available from: https://www.nature.com/articles/534320a
4. Kumar S, Kumar N, Vivekadhish S. Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs): addressing unfinished agenda and strengthening sustainable development and partnership. J Family Med Prim Care. 2016;5(2):238-42. Available from: https://doi.org/10.4103/0970-0218.170955

Citation: Donkor FK. Addressing the Impact of Pesticides on the Food Chain for Human and Ecosystem Health. Food Sci Nutr The. 2026;12(1):9-16. Available from: https://dx.doi.org/10.17352/jfsnt.000060

5. Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM, et al. Planetary boundaries: guiding human development on a changing planet. Science. 2015;347(6223):1259855. Available from: https://doi.org/10.1126/science.1259855
6. Griggs D, Stafford-Smith M, Gaffney O, Rockström J, Öhman MC, Shyamsundar P, et al. Sustainable development goals for people and planet. Nature. 2013;495(7441):305-7. Available from: https://doi.org/10.1038/495305a
7. Biermann F, Kanie N, Kim RE. Global governance by goal-setting: the novel approach of the UN Sustainable Development Goals. Curr Opin Environ Sustain. 2017;26-27:26-31. Available from: www.sciencedirect.com/science/article/pii/S1877343517300209
8. Moyer JD, Hedden S. Are we on the right path to achieve the Sustainable Development Goals? World Dev. 2020;127:104749. Available from: https://www.sciencedirect.com/science/article/pii/S0305750X19303985
9. Sachs JD, Lafortune G, Kroll C, Fuller G, Woelm F. Sustainable development report 2022. Cambridge: Cambridge University Press; 2022.
10. Spangenberg JH. Hot air or comprehensive progress? A critical assessment of the SDGs. Sustain Dev. 2017;25(4):311-24. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/sd.1657
11. Easterly W. The SDGs should stand for senseless, dreamy, garbled. Foreign Policy. 2015 Sep 1. Available from: Foreign Policy
12. Population Matters. The SDGs. 2025. Available from: Population Matters
13. Millennium Ecosystem Assessment. Ecosystems and human well-being: synthesis. Washington (DC): Island Press; 2005.
14. Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, et al. The value of the world's ecosystem services and natural capital. Nature. 1997;387(6630):253-60. Available from: https://www.nature.com/articles/387253a0
15. Food and Agriculture Organization of the United Nations. Status of the world's soil resources: main report. Rome: FAO; 2015.
16. Shackleton CM, Shackleton SE, Gambiza J. The role of non-timber forest products in rural livelihoods. For Trees Livelihoods. 2011;20(2-3):110-20.
17. Daily GC, editor. Nature's services: societal dependence on natural ecosystems. Washington (DC): Island Press; 1997.
18. Costanza R, de Groot R, Sutton P, van der Ploeg S, Anderson SJ, Kubiszewski I, et al. Changes in the global value of ecosystem services. Glob Environ Change. 2014;26:152-8. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0959378014000685
19. The Economics of Ecosystems and Biodiversity. The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB. Nairobi: United Nations Environment Programme; 2010.
20. Ramsar Convention Secretariat. Global wetland outlook: state of the world's wetlands and their services to people. Gland (Switzerland): Ramsar Convention Secretariat; 2018.
21. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. The assessment report on pollinators, pollination and food production. Bonn (Germany): IPBES; 2016.
22. Cardinale BJ, Duffy JE, Gonzalez A, Hooper DU, Perrings C, Venail P, et al. Biodiversity loss and its impact on humanity. Nature. 2012;486(7401):59-67. Available from: https://www.nature.com/articles/nature11148
23. Daily GC, Matson PA. Ecosystem services: from theory to implementation. Proc Natl Acad Sci U S A. 2008;105(28):9455-6. Available from: https://www.pnas.org/doi/10.1073/pnas.0804960105
24. Montgomery DR. Soil erosion and agricultural sustainability. Proc Natl Acad Sci U S A. 2007;104(33):13268-72. Available from: https://www.pnas.org/doi/10.1073/pnas.0611508104
25. Pereira HM, Leadley PW, Proença V, Alkemade R, Scharlemann JPW, Fernandez-Manjarrés JF, et al. Scenarios for global biodiversity in the 21st century. Science. 2010;330(6010):1496-501. Available from: https://www.science.org/doi/10.1126/science.1196624
26. Chan KM, Satterfield T, Goldstein J. Rethinking ecosystem services to better address and navigate cultural values. Ecol Econ. 2012;74:8-18. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0921800911004927
27. Cocks ML, Wiersum KF. Reappraising the concept of biocultural diversity: a perspective from the social sciences. Biodivers Conserv. 2014;23(5):1173-94.
28. Daniel TC, Muhar A, Arnberger A, Aznar O, Boyd JW, Chan KM, et al. Contributions of cultural services to the ecosystem services agenda. Proc Natl Acad Sci U S A. 2012;109(23):8812-9. Available from: https://www.pnas.org/doi/10.1073/pnas.1114773109
29. Jenny H. Factors of soil formation: a system of quantitative pedology. New York (NY): McGraw-Hill; 1941.
30. Lal R. Restoring soil quality to mitigate soil degradation. Sustainability. 2015;7(5):5875-95. Available from: https://www.mdpi.com/2071-1050/7/5/5875
31. Fierer N. Embracing the unknown: disentangling the complexities of the soil microbiome. Nat Rev Microbiol. 2017;15(10):579-90. Available from: https://www.nature.com/articles/nrmicro.2017.87
32. Bardgett RD, van der Putten WH. Belowground biodiversity and ecosystem functioning. Nature. 2014;515(7528):505-11. Available from: https://www.nature.com/articles/nature13855
33. Smith SE, Read DJ. Mycorrhizal symbiosis. 3rd ed. London: Academic Press; 2008.
34. Wall DH, Nielsen UN, Six J. Soil biodiversity and human health. Nature. 2015;528(7580):69-76. Available from: https://www.nature.com/articles/nature15744
35. Lal R. Soil carbon sequestration impacts on global climate change and food security. Science. 2004;304(5677):1623-7. Available from: https://www.science.org/doi/10.1126/science.1097396
36. Paustian K, Lehmann J, Ogle S, Reay D, Robertson GP, Smith P. Climate-smart soils. Nature. 2016;532(7597):49-57. Available from: https://www.nature.com/articles/nature17174
37. Power AG. Ecosystem services and agriculture: tradeoffs and synergies. Philos Trans R Soc Lond B Biol Sci. 2010;365(1554):2959-71. Available from: doi:10.1098/rstb.2010.0143.
38. Jones CG, Lawton JH, Shachak M. Organisms as ecosystem engineers. Oikos. 1994;69(3):373-86. Available from: https://doi.org/10.1155/2022/3545850
39. Copley J. Ecology goes underground. Nature. 2000;406(6795):452-4. Available from: https://doi.org/10.1038/35020131
40. Food and Agriculture Organization of the United Nations. Global assessment of soil biodiversity. Rome: FAO; 2020.
41. Tully K, Sullivan C, Weil R, Sanchez P. The state of soil degradation in sub-Saharan Africa. Agric Ecosyst Environ. 2015;204:25-36.
42. Bouma J. Soil science contributions towards sustainable development goals. Soil. 2015;1(1):111-22. Available from: https://www.researchgate.net/publication/261560032_Soil_science_contributions_towards_Sustainable_Development_Goals_and_their_implementation_linking_soil_functions_with_ecosystem_services

Citation: Donkor FK. Addressing the Impact of Pesticides on the Food Chain for Human and Ecosystem Health. Food Sci Nutr The. 2026;12(1):9-16. Available from: https://dx.doi.org/10.17352/jfsnt.000060

43. United Nations. The 17 goals. New York (NY): United Nations; 2022. Available from: United Nations Sustainable Development Goals

44. Khosravi Mashizi A, Sharafatmandrad M. Linking ecosystems to public health based on a combination of social and ecological systems. Sci Rep. 2024;14:9911. Available from: https://doi.org/10.1038/s41598-024-60814-z

45. Dakubo CY. Exploring the linkages between ecosystems and human health. In: Dakubo CY, editor. Ecosystems and human health. Dordrecht: Springer; 2010. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC7122048/

46. Leviston Z, Walker I, Green M, Price J. Linkages between ecosystem services and human wellbeing: a Nexus Webs approach. Ecol Indic. 2018;93:658-68.

47. Mohd Ghazi R, Nik Yusoff NR, Abdul Halim NS, Wahab IRA, Ab Latif N, Hasmoni SH, et al. Health effects of herbicides and their current removal strategies. Bioengineered. 2023;14(1):2259526. Available from: doi:10.1080/21655979.2023.2259526.

48. Parven A, Meftaul IM, Venkateswarlu K, et al. Herbicides in modern sustainable agriculture: environmental fate, ecological implications, and human health concerns. Int J Environ Sci Technol (Tehran). 2025;22:1181-202. Available from: https://www.researchgate.net/publication/381549025_Herbicides_in_modern_sustainable_agriculture_environmental_fate_ecological_implications_and_human_health_concerns

49. Campos Ventura-Camargo MA, de Campos Ventura-Camargo B, Miyuki M. Toxicity of herbicides: impact on aquatic and soil biota and human health. In: Herbicides - current research and case studies in use. London: InTech; 2013.

50. Tudi M, Daniel R H, Wang L, Lyu J, Sadler R, Connell D, et al. Agriculture development, pesticide application and its impact on the environment. Int J Environ Res Public Health. 2021;18(3):1112. Available from: https://doi.org/10.3390/ijerph18031112

51. Zhang H, Chen S, Zhang Q, Long Z, Yu Y, Fang H. Fungicides enhanced the abundance of antibiotic resistance genes in greenhouse soil. Environ Pollut. 2020;259:113877.

52. Kumar M, Yadav AN, Saxena R, Paul D, Tomar RS. Biodiversity of pesticides-degrading microbial communities and their environmental impact. Biocatal Agric Biotechnol. 2021;31:101883. Available from: https://hero.epa.gov/reference/7428499/

53. Zhang YF, Zhang YH. Green pesticide practices and sustainability: empirical insights into agricultural services in China. Int J Agric Sustain. 2024;22(1):2306713.

54. Zou M, Zhou S, Zhou Y, Jia Z, Guo T, Wang J. Cadmium pollution of soil-rice ecosystems in rice cultivation-dominated regions in China: a review. Environ Pollut. 2021;280:116965. Available from: https://doi.org/10.1016/j.envpol.2021.116965

55. Wu M, Zhang W, Miao J, Sun C, Wang Q, Pan L. Pyrethroid contamination and health risk assessment in seafood collected from the coast of Shandong, China\

56. Khan BA, Nadeem MA, Nawaz H, Amin MM, Abbasi GH, Nadeem M, et al. Pesticides: impacts on agriculture productivity, environment, and management strategies. In: Emerging contaminants and plants: interactions, adaptations and remediation technologies. Cham: Springer; 2023. p. 109-34.

57. Hickel J. The contradiction of the sustainable development goals. Globalizations. 2019;16(6):873-88.

58. Bennett EM, Peterson GD, Gordon LJ. Understanding relationships among multiple ecosystem services. Ecol Lett. 2009;12(12):1394-404. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1461-0248.2009.01387.x

59. Cardinale BJ, Duffy JE, Gonzalez A, Hooper DU, Perrings C, Venail P, et al. Biodiversity loss and its impact on humanity. Nature. 2012;486(7401):59-67. Available from: https://www.nature.com/articles/nature11148

60. Scholes RJ, Walters M, Turak E, et al. Spatial data for the identification of biodiversity hotspots and ecosystem services in Africa.

61. Gunstone T, Cornelisse T, Klein K, Dubey A, Donley N. Pesticides and soil invertebrates: a hazard assessment. Front Environ Sci. 2021;9:643847. Available from: https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2021.643847/full

62. European Commission, Directorate-General for Health and Food Safety; Feijao C, d'Angelo C, Flanagan I, Abellan B, Gloinson ER, Smith E, et al.

63. Development of future scenarios for sustainable pesticide use and achievement of pesticide-use and risk reduction targets announced in the Farm to Fork and Biodiversity Strategies by 2030: final report. Luxembourg: Publications Office of the European Union; 2022.

64. Ahmad MF, Ahmad FA, Alsayegh AA, Zeyaullah M, AlShahrani AM, Muzammil K, et al. Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures. Heliyon. 2024;10(7):e29128. Available from: https://www.sciencedirect.com/science/article/pii/S2405844024051594

65. Boedeker W, Watts M, Clausing P, Marquez E. The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review. BMC Public Health. 2020;20(1):1875. Available from: https://link.springer.com/article/10.1186/s12889-020-09939-0