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ORIGINAL ARTICLE

From soils to guts: exploring the narratives about the microbiome's potential to integrate agrifood and healthcare systems

Shana L. Hepping[1] · **Gerard Breeman**[1] · **Eefje Cuppen**[1]

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Abstract

The microbiome represents a promising avenue for integrating agrifood and healthcare systems, offering the potential to address interconnected challenges such as environmental sustainability, food security, and public health. This study investigates the microbiome as an emerging discourse and explores its capacity to integrate these sectors, fostering systemic transformations through a systems-thinking lens. Using qualitative interviews with farmers, researchers, dietitians, and healthcare practitioners, and employing narrative analysis, the research identifies how stakeholders perceive the microbiome's potential for integration. Findings reveal that the microbiome is increasingly recognized for its critical role in human health with narratives such as *Food as Medicine* and *Farmer as Doctor* gaining traction. This research examines the potential of the microbiome as a concept that bridges agrifood and healthcare systems, highlighting both opportunities and barriers. Narratives like *Farmer as Doctor* and *Food as Medicine* promote integration by emphasizing microbial diversity and ecosystem health, but remain siloed within their respective sectors. The resulting disconnect impedes collaboration and transformative change. By reframing health through an ecosystemic perspective that links soil, food, and human well-being, the microbiome challenges traditional paradigms. However, unlocking its integrative potential requires systemic changes, shared narratives, and cross-sectoral collaboration to align diverse stakeholders around a vision of sustainability and health. This research contributes to ongoing discussions on leveraging the microbiome as a concept linking sustainability and health, highlighting the importance of interdisciplinary collaboration to move from conceptual discussions to actionable solutions. By addressing these systemic barriers, the microbiome could catalyze a broader shift toward integrative, sustainable practices across agrifood and healthcare systems.

Keywords Microbiome · Agrifood systems · Healthcare integration · Systemic transformation · Sustainability · One Health

Introduction

Humanity faces a convergence of critical global challenges with consequences for human and planetary health. Environmental crises such as climate change (IPCC 2022) and biodiversity loss (IPBES 2019) are coupled with public health challenges, including unbalanced diets (Lindgren et al. 2018), and the rising prevalence of non-communicable diseases such as diabetes and obesity (Di Cesare 2019). These issues are further exacerbated by escalating healthcare costs, which in 2021 accounted for more than 10% of global GDP (WHO 2024). Addressing these interconnected challenges requires far-reaching transformative action across technological, economic, political, social, and cultural systems.

Two critical systems at the heart of these challenges are agrifood and healthcare. Unsustainable agricultural practices drive biodiversity loss and degrade vital resources like soil and water (WWF 2024), while healthcare systems primarily focus on treating symptoms rather than preventing diseases. This treatment-centered model relies heavily on medications, neglecting preventive measures (Federoff and Gostin 2009; Pryor and Volpp 2018). Agrifood and health can be seen as interconnected. For instance, industrialized food production contributes to poor diets, which are linked to obesity, diabetes, and cardiovascular diseases (Afshin et al. 2019), while soil degradation decreases the nutritional value

Handled by Barbara Schröter, Leibniz Centre for Agricultural Landscape Research (ZALF), Germany.

✉ Shana L. Hepping
s.l.hepping@fgga.leidenuniv.nl

[1] Institute of Public Administration, Leiden University, The Hague, The Netherlands

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of crops, worsening human malnutrition (Lal 2009). Additionally, unsustainable farming contributes to climate change and biodiversity loss, which amplify health risks such as malnutrition and vector-borne diseases (IPCC 2022; WHO 2017). Together, these systems perpetuate a cycle of environmental harm and poor health outcomes, rooted in paradigms that prioritize economic growth over environmental and social well-being (Raworth 2018; Riedy and Waddock 2022; Sanders 2023).

The misalignment between the healthcare and agricultural sectors reinforces siloed approaches, hindering the development of integrated solutions like preventive healthcare initiatives grounded in healthy diets. A clear example of this disconnect is the contradiction between dietary guidelines, which advocate for reducing animal-based fats, and agricultural policies that continue to subsidize meat and dairy production (Lobstein 2002). Such conflicting governance frameworks undermine efforts to develop responses to interconnected health and environmental challenges (Roos et al. 2006). Addressing these issues requires a shift toward systems thinking, which highlights the interdependence and complexity of these sectors, as emphasized by academics across both fields (Candel and Pereira 2017; Fiandaca et al. 2017; Meadows 2008).

One potential solution is the development of a "Healthy Food System", an integrative approach that aligns agrifood and healthcare with prioritizing human and ecological health. Food and eating function as natural connectors, providing a pathway to bridge the gap between the two systems. Initiatives such as One Health (WHO 2017) and Planetary Health (Horton et al. 2014) offer integrative views on agrifood and health. Similarly, policies like the EU's Farm to Fork strategy (Commission 2020) and frameworks like the EAT-Lancet planetary health diet (Willett et al. 2019) aim to align agrifood and health goals. Despite these efforts, implementing integrated food system approaches remains limited, with significant governance challenges and unresolved questions (e.g., Candel and Pereira 2017).

A promising development in transforming agrifood and healthcare systems is the rise of the microbiome as an influential concept that potentially inspires a food system that benefits both human and planetary health. Encompassing microorganisms and their interactions within ecosystems (Berg et al. 2020; Whipps et al. 1988), the microbiome draws attention to the biological connection between soil, plant, environmental and human health (Banerjee and van der Heijden 2023; Erisman 2021; Manghi et al. 2024). While early research primarily focused on the human gut microbiome (e.g., Vijay and Valdes 2022), the scope of the field has expanded to include soil and plant microbiomes (Hannula et al. 2020; Pineda et al. 2020). The plant microbiome refers to the microbial communities that inhabit plant tissues, such as roots, leaves, and stems, which are distinct from but influenced by the surrounding soil microbiome (Mantegazza et al. 2023; Wassermann et al. 2019), revealing essential links between agricultural practices, biodiversity, and human well-being (Frąc et al. 2022; Morriën et al. 2017). The microbiome is best seen as a boundary concept: one that opens up new questions and points of connection between previously siloed sectors (Hoppe 2010; Klein 2021). The idea of human–microbiome symbiosis signals a potential shift from pathogen-focused approaches toward strategies that support microbial diversity to improve soil health, crop resilience, and human well-being (Paxson and Helmreich 2014; Rees et al. 2018). This shift aligns with a broader move toward sustainable practices, reducing dependence on chemical inputs and enhancing natural resilience. As reservoirs of microbial diversity, soils play a foundational role in this transformation. Prioritizing soil health and microbial ecosystems can unite agrifood and healthcare practices, supporting both ecological and human health (Barros-Rodríguez et al. 2021; Khmelevtsova et al. 2022; Lal 2009).

This study examines the narratives about the microbiome within agrifood and healthcare systems, investigating its potential as a boundary concept for integrative transformation. Based on the analysis of stakeholder narratives, we assess the challenges and opportunities of leveraging the microbiome to create synergies between these sectors. Conducted as part of the Soils2Guts consortium in the Netherlands,[1] this research integrates insights from microbiology, agriculture, healthcare, and governance. The Soils2Guts project specifically explores how sustainable agricultural practices can enhance soil and crop microbiomes, to improve human gut health and reduce non-communicable diseases through a holistic approach. By bridging the traditionally siloed domains of agriculture and healthcare, the study positions the microbiome as a concept contributing toward systemic change.

While the microbiome's role in human health has been extensively studied (Berg et al. 2020), its societal and governance implications remain underexplored. This research addresses this gap by asking, *"What narratives about the microbiome can be identified within agrifood and healthcare systems, and how integrative are these?"* It seeks to align efforts toward developing a socioecological Healthy Food System, advocating for a transdisciplinary approach that emphasizes the interconnectedness of human and ecological health. As the microbiome continues to emerge as an interdisciplinary field, it fosters collaborations that could reshape how we address complex sustainability challenges (Nishi et al. 2022; Riechers et al. 2021; Westley et al. 2002). This study contributes to understanding how these efforts

[1] See soils2guts.org.

can integrate microbiome science within a broader sustainability framework.

Theoretical framework

Complex systems and the case for integration

The agrifood and healthcare sectors are distinct yet deeply interconnected, influencing each other across ecological, economic, political, and social dimensions (Afshin et al. 2019; FAO et al. 2023; Roos et al. 2006). Their integration demands a holistic, systems-thinking approach (Voulvoulis et al. 2022) that addresses both practical solutions and the underlying values, principles, and relationships driving transformation (Bentz et al. 2022). Fundamental changes are necessary in both sectors, as priorities of human and ecological health often clash with existing paradigms focused on short-term economic growth (Hall 1993; Meadows 1999; Riedy and Waddock 2022; Zywert 2017).

The pursuit of systemic transformation is challenging due to the inherent complexity of the agrifood and healthcare systems. These systems involve multiple levels and diverse actors with distinct perspectives, resources, and constraints (Lahsen and Turnhout 2021). At the micro level, local farmers and health workers address consumer and patient needs. The meso level includes hospitals and regional health authorities coordinating broader efforts, while the macro level involves policymakers, regulators, and corporations. Transformation is complicated by the interdependence across these levels, especially when powerful incumbents, such as pharmaceutical and agribusiness firms, may resist changes that threaten their interests (Bentz et al. 2022; Lahsen and Turnhout 2021; Raposo et al. 2022). The systems, including their multiple levels, are captured in Fig. 1.

Deep transformation in agrifood and healthcare systems

Achieving sustainability in agrifood and healthcare requires a profound transformation that goes beyond superficial adjustments to address the deep, underlying beliefs and structures of these systems (Ehrenfeld 2004; Meadows 1999). While much of the current literature on transformation focuses on "shallow" interventions like policy changes and financial tools, these efforts primarily address surface-level mechanisms and tend to produce limited change (Dorninger et al. 2020). Shallow interventions are important for setting the stage and raising awareness, but they do not challenge the entrenched norms, values, and power dynamics that govern a system (Abson et al. 2017). Examples of shallow change include agricultural subsidies for nutrient-dense production or incorporating microbiome measurements into medical diagnoses and treatments. While these actions may not directly confront social norms, they can serve as "sparks" for deeper shifts in attitudes and behaviors,

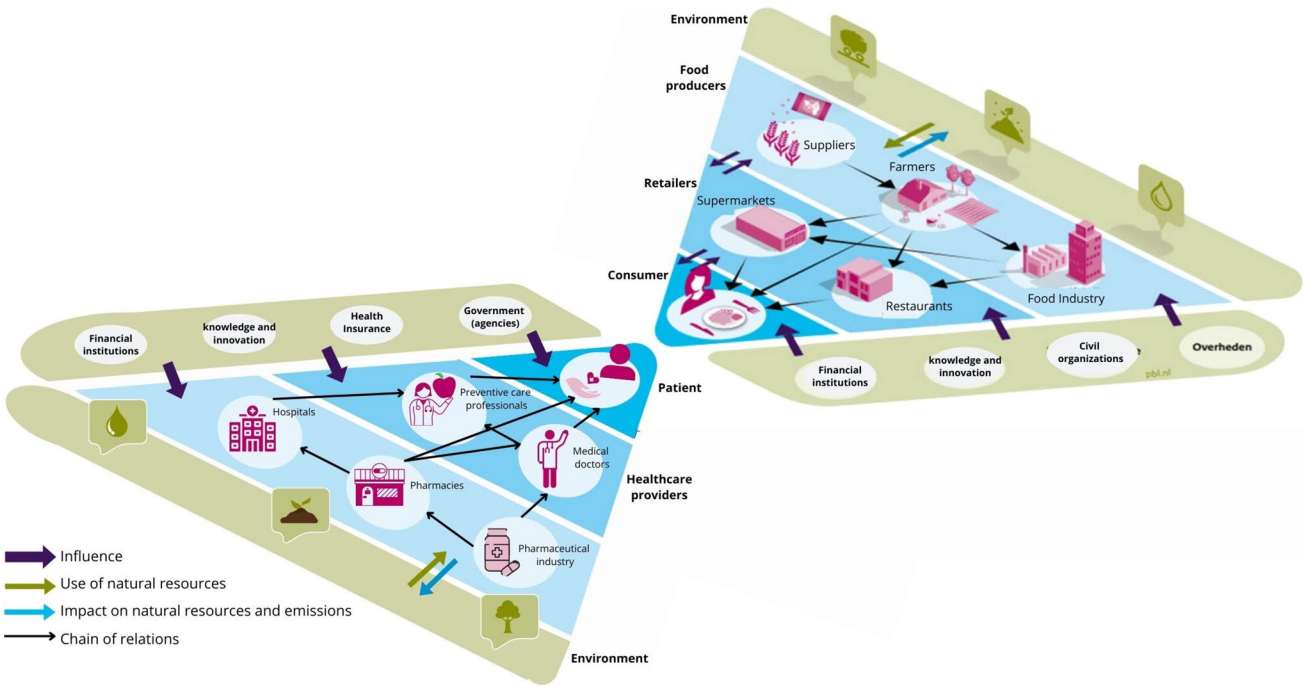

Fig. 1 Agrifood and health as an integrated socioecological system. The right side (agrifood) was adapted from PBL (2020), left side (healthcare) is the authors' own addition

enabling the conditions for more profound transformation (Few et al. 2017; Manlosa et al. 2019).

Systemic change involves a shift at the level of paradigms, the deepest “leverage points” in a system (Meadows 1999). Paradigms form the fundamental worldview underpinning a system’s goals, governance, and practices (Hall 1993; Hogan and Howlett 2015). Aligning these paradigms with sustainability can initiate transformative change across the system, reshaping governance frameworks and redefining social values (Few et al. 2017). However, paradigm shifts are inherently challenging because they confront deeply held beliefs, vested interests, and established practices (Skogstad 1998). For instance, industries benefiting from the status quo may lobby against reforms (e.g., Lelieveldt 2023), while cultural norms and professional practices may reinforce existing paradigms. Despite these obstacles, paradigm shifts offer great potential for creating an integrated, sustainable Healthy Food System.

Historical examples illustrate the transformative power of such shifts. The creation of the Common Agricultural Policy (CAP), which transformed EU agriculture from traditional, small-scale farming to more industrialized practices, highlights how altering goals and governance structures can revolutionize a sector (Daugbjerg and Feindt 2022). Similarly, the shift from believing in the miasma theory—the idea that diseases were caused by "bad air"—toward embedding the germ theory of disease into the healthcare system (Verhaeghe 2012), demonstrates systemic change following a new paradigm taking hold.

Deep transformation requires questioning the foundational assumptions and values that shape how individuals and societies perceive their relationship with nature, systems, and each other (O'brien 2021). At the heart of this process are narratives and frameworks that space collective understanding and meaning (Keller 2024). Narratives influence societal norms, policies, and values, guiding the goals and practices of entire systems (Hajer 1995). The microbiome represents a powerful emerging concept that reimagines the interconnectedness of health, food, and ecology. It shifts the story from one of separation, where agrifood and healthcare operate in silos, to one of integration, emphasizing how human health is inseparable from the health of soils, plants, and animals (Riedy 2020; Voulvoulis et al. 2022). By describing the microbiome as a boundary concept, this research highlights its potential to inspire new ways of thinking and acting, inspiring the cultural and social change necessary to align agrifood and healthcare systems with sustainable futures (Berzonsky and Moser 2017; Klein 2021).

Narratives are stories that structure and convey meaning by connecting events, actions, and values into a sequence to influence understanding, behavior, and decision-making (Anderson and Rivera-Ferre 2021). They are not static; they evolve dynamically, reflecting shared language, and concepts that guide discussions in specific fields (Hajer 2002; Oels 2005; Phillips and Jorgensen 2002). For instance, the term "gut microbiome" in medicine signifies an understanding that influences both research and practice. By encouraging shared patterns of meaning that explain phenomena, identify problems, and propose solutions (Fiala et al. 2024; Lübker et al. 2021; Riedy 2020; Van Hulst et al. 2025), narratives can catalyze transformative change. These narratives enable individual and collective sense-making (Foucault and Howard 1965; Keller 2024) and offer opportunities to challenge dominant paradigms while imagining alternative futures (Darier 1999; Riedy and Waddock 2022).

The microbiome as a boundary concept for a coupled systemic transformation in agrifood and health

The meaning and implications of the microbiome for agrifood and health have not yet been clearly defined. As such, it may act as a boundary concept, a flexible idea that resonates with different domains and brings actors from those domains together to discuss shared meanings and objectives that contributes to coupled sustainable transformation in those sectors (Runhaar 2017). Traditionally, agrifood and healthcare have been framed separately, both dominated by a neoliberal paradigm. In agrifood, this is reflected in productionism and cost-effectiveness (Daugbjerg and Feindt 2019; Fiala et al. 2024; Raworth 2018; Vincent and Feola 2020; Wojtynia et al. 2021), while in healthcare it manifests through patient consumerism and symptomatic treatment (Kamel et al. 2024; Pryor and Volpp 2018). The microbiome, however, may introduce a new, integrative perspective that emphasizes the interconnectedness of human and ecological health (Banerjee and van der Heijden 2023), challenging these approaches. By reframing food as inherently important to human and ecological health and highlighting the mutual reinforcement of sustainable agriculture and preventive healthcare, the microbiome shifts attention toward ecosystemic approaches that align with broader sustainability goals. By mapping existing narratives about the microbiome within agrifood and healthcare systems, this research evaluates their potential to bridge sectors, challenge entrenched paradigms, and drive systemic change. This approach assesses not only the conceptual power of narratives about the microbiome, but also their practical capacity to inspire cross-sector collaboration and align efforts toward an integrative vision of health and sustainability. Such an evaluation helps identify both barriers and opportunities, informing actionable strategies to advance transformation.

Methods

Data collection

We interviewed pioneering stakeholders in the agrifood and healthcare sectors who actively advocate for integrating the microbiome into their practices and thinking. Although not yet mainstream, these 'mavericks' have integrated microbiome-related practices into their work or support their adoption at institutional levels. Our sample spanned both systems and included actors across micro, meso, and macro levels, in line with our conceptual framework.

Data collection took place in multiple rounds. Initially, purposive sampling was used to select participants. We selected key stakeholders in both the agrifood and healthcare sectors through our network and that of the Soil2Guts consortium. The first round consisted of 7 interviews. This was followed by an open call on LinkedIn, broadening the participant pool and increasing the likelihood of reaching diverse perspectives on microbiome practices across different professional backgrounds. This resulted in 6 additional interviews. Snowball sampling, i.e., recommendations from interviewed stakeholders, was used to add another 11 interviews. This led to a total of 24 interviews (see Table 1).

Each interview lasted 1–1.5 h. Most interviews were conducted via Microsoft Teams, with some held in person. Although individual consumers or patients were not directly interviewed, their perspectives often surfaced through dieticians discussing patients or agriculture professionals reflecting on consumer viewpoints.

The interviews followed a semi-structured, problem-centered format, which encouraged storytelling and subjective expression (Cunliffe and Shotter 2013). The interview guide was adapted to each participant's context, with follow-up questions tailored to topics raised by participants (Lübker et al. 2021). A copy of the interview guide is included in the supplementary materials. Questions focused on the microbiome, changes in knowledge and practice, and envisioned futures for agrifood and healthcare over the next decade, including the microbiome's potential role in that future. Without prompting, participants independently mentioned paradigmatic shifts, systemic integration, and holistic governance. Although narrative analysis often applies to pre-existing data, conducting it on interview data requires adapting interview questions to evoke detailed, narrative responses (Nissi and Pälli 2020). For instance, prompts such as "Take me back to when you first encountered the microbiome" encouraged participants to share stories. Neutral, short probes minimized interviewer influence, allowing participants to use their own language. All interviews were recorded, transcribed, and pseudonymized for confidentiality.

Table 1 List of participants

Unique identifier	Domain	Actor type	Level
I1	Agrifood	Farmer	Micro
I2	Agrifood	Farmer	Micro
I3	Agrifood	Integrative health consultant	Micro
I4	Agrifood	Farming Interest organization	Macro
I5	Agrifood	Civil society organization	Meso
I6	Agrifood	Civil society organization	Meso
I7	Agrifood	Supermarket	Meso
I8	Agrifood	Agricultural consultancy agency	Meso
I9	Agrifood	Researcher	Meso
I10	Agrifood	Researcher	Meso
I11	Agrifood	Seed breeder	Meso
I12	Healthcare	Health entrepreneur	Micro
I13	Healthcare	Dietician	Micro
I14	Healthcare	Health clinic	Meso
I15	Healthcare	Laboratory	Meso
I16	Healthcare	Dietician	Micro
I17	Healthcare	Researcher	Meso
I18	Healthcare	Health foundation	Macro
I19	Healthcare	Health entrepreneur	Meso
I20	Healthcare	Health foundation	Macro
I21	Healthcare	General practitioner	Micro
I22	Healthcare	Health monitor	Macro
I23	Healthcare	General practitioner	Micro

Data analysis

This study employs narrative analysis to explore how stakeholders in agrifood and healthcare systems discuss the microbiome and its potential to integrate these fields (Anderson 2024; Hajer 2002; Riedy 2020). Using an abductive approach, we analyzed interview data to identify recurring themes, language patterns, and narratives that shape perceptions of the microbiome across these sectors.

The first step of the analysis involved open coding of interview transcripts, based on the approach by Saldaña (2016). We aimed to identify recurring themes and patterns related to the microbiome. Themes emerged around three core dimensions: attitude toward the microbiome, its potential to integrate sectors, and its role in systemic transformation. These initial themes were partially informed by academic literature on food policy integration and microbiome perceptions. To ensure empirical grounding, we conducted an iterative refinement of codes after analyzing seven initial interviews. During this phase, codes were adjusted and aligned with participants' views, allowing for the identification of key narrative elements and consistent patterns.

Building on the themes identified during the initial coding, the second step involved refining these categories to

develop analytical dimensions for structuring the narratives. Using a typology approach (Kluge 2000), recurring patterns in the data, such as ecocentric thinking, sustainability goals, and cooperative relationships, were synthesized into three evolved dimensions: (1) attitudes toward the microbiome, (2) its role in systemic transformation, and (3) its potential to integrate sectors. These dimensions represent an advanced iteration of the initial themes discerned earlier. These dimensions provided a framework for refining and reorganizing the initial codes. For example, shared goals across actors were mapped onto these dimensions, helping to differentiate the narratives and to ensure that patterns across transcripts were systematically captured (see Table 2). Case summaries were then grouped by similarities within each dimension, facilitating a clearer understanding of how participants aligned with the identified themes (Fiala et al. 2024).

The final step involved constructing narratives to distinguish participants' perspectives across the three dimensions outlined in the previous steps (Riedy and Waddock 2022). This process entailed grouping case summaries and codes into cohesive narratives that captured the diversity of viewpoints. This step also explored how professional roles and the actor's level of operation aligned with specific narratives. By systematically mapping these distinctions, the analysis highlighted how narratives about the microbiome vary across sectors and actor types, offering insights into its emerging role in bridging agrifood and healthcare systems.

Results

Our analysis revealed a spectrum of narratives across both the agrifood and healthcare sectors, reflecting varied attitudes toward the microbiome, perspectives on integrating the agrifood and healthcare systems, and perspectives on transforming either system. Five narratives emerged from this analysis: *Farmer as Doctor*, *Soil Microbiome for Agricultural Innovation*, *Food as Medicine*, *Gut Microbiome for Preventive Health*, and *Microbial Risk and Food Safety*, see Table 3 for a summary of the narratives.

Farmer as Doctor: extending agrifood toward healthy food for healthy people

In the agrifood sector, there is a growing recognition of farmers not only as food producers, but as "*soil doctors*" (I17) who can influence public health through the quality of the food they cultivate. Within this narrative, healthy soil is often associated with rich and diverse microbial communities and framed as linked to human microbiome health, reflecting a broader discourse that emphasizes ecological interconnectedness between environmental and human systems, rather than a direct causal relationship. Validating this connection scientifically is seen as essential (I13), as it may reinforce the credibility of this narrative. At present, references to "*gut feeling*" (I5) or "*instinct*" (I1) highlights an embodied or intuitive sense of connection between health, food, and the land. While not yet anchored in formal scientific evidence, this kind of affective response may serve as an experiential foundation for emerging ecological or systemic understandings. This perspective is transformative as it aims to reorient social values in the agrifood system, which currently prioritizes high yields over soil health, compromising the nutrient quality of food. "*I partly think that we have gone too far with our innovation and the idea that we can solve everything with technology […]. We have to look at the solutions that nature offers us and then everyone can use them*" (I6). Microbiome-inclusive agriculture is presented as an alternative, promising sustainable and equitable food production: "*The microbiome is taking us away from thinking about food system solely from a chemistry perspective and it adds the biology, it makes people realize that it's not just about […] adding more inorganic minerals to the soil. No, it's about cultivating the life below the ground*" (I9).

The microbiome's integrative potential, as articulated by this narrative, centers on sustainable agricultural practices that directly support human health by promoting microbial diversity in both soils and guts. This perspective often aligns with the growing emphasis on local food systems gaining importance (I6), which are seen as better able to maintain microbial integrity across the food chain. By shortening

Table 2 Construction of dimensions, based on coding categories and informed by the literature

Dimensions	Codes	Literature
Attitude toward the microbiome	Microbiome as foundational; microbiome as balancing; microbiome as a tool for innovation; complexity; interconnectedness	Brives et al. (2021), Kokkinias et al. (2024), Paxson and Helmreich (2014), Rees et al. (2018)
Perspective on transformation	Shifting paradigm; microbiome as catalyst for transformation; ecosystem health; holistic approach; new microbiome-related practices	Kuhmonen (2017), Neish et al. (2017), Riedy and Waddock (2022)
Perspective on Integrative power	Synergy agrifood and health; barriers to integration; shared language; best practices of innovation; systemic interdependence	Briassoulis (2005), Galli et al. (2020), Lobstein (2002)

Table 3 Summary of narratives along the three dimensions

Narrative	Perspective on microbiome	Perspective on transformation	Perspective on integrative power	Key actors
Farmer as Doctor	Microbiome is key to promoting ecosystem and human health; microbiome is critical to sustainable farming	Radical shift toward farming practices focused on soil, human and ecosystem health	Strong connection between agrifood and health through nutrient-dense, microbiome-friendly foods	Farmers, agronomists, agrifood advisors
Soil Microbiome for Agricultural Innovation	Microbiome is instrumental in technological innovation	Market-driven approach of innovations within the current industrial system	Limited focus on agrifood-health integration; primarily agricultural applications	Farmers, food chain partners, retailers, food companies
Food as Medicine	Microbiome is key to promoting ecosystem and human health; microbiome is critical to healthcare	Paradigm shift in healthcare from reactive to preventive, emphasizing diet-based interventions	Strong connection between agrifood and health through nutrient-dense, microbiome-friendly foods	Doctors, dieticians, medical researchers
Gut Microbiome for Preventive Health	Microbiome as a personalized health tool for diagnostics, nutrition, and therapeutic care	Paradigm shift in healthcare from reactive to preventive, emphasizing diet-based interventions	Weak connection to agrifood; focused on healthcare system innovation	Medical researchers, healthcare providers
Microbial Risk and Food Safety	Dual: potential health benefits vs. microbial risks (e.g., pathogens)	Cautious, evidence-based progress to address safety concerns	Limited: regulatory and safety concerns create barriers to agrifood-health integration	Food safety regulators, public health researchers, food processing industry

supply chains and encouraging practices such as minimal processing, reduced antibiotic use, and regenerative farming, local systems are perceived to strengthen the connection between soil and human health.

Soil Microbiome for Agricultural Innovation

This narrative positions the microbiome as a promising frontier for agricultural innovation, emphasizing its potential to improve soil health and enhance plant resilience. Companies within the food system are actively investing in microbiome-friendly technologies, such as fertilizers and soil enhancers, aimed at creating "*resilient crops and healthier soils*" (I8). However, this enthusiasm is tempered by concerns about whether the microbiome is merely a "buzzword," given that much of the research remains in the technical phase. One participant captures these doubts: *"I see that people are doing a lot of research into […] things that you can control in the soil to make roots more resilient. […] We are actually waiting to see where we can get practical tools or guidance for growers*" (I4).

This narrative focuses on a technical, market-centered approach to the microbiome, navigating the tensions between sustainable farming practices and the dominant industrial agricultural model, which frequently prioritizes yield over ecosystem health. One farmer who spends a lot of time and energy in caring for their soil illustrates this disconnect: *"I'm busy with selling healthy vegetables from healthy soil, but it's brought to the cooperative, which throws my potatoes back on the big pile. As a result, the healthy character [of my produce] is lost in the market"* (I2). The quote reflects systemic barriers to aligning microbiome-focused agriculture with market demands, which prioritize volume and standardization over quality and differentiation.

Unlike the transformative aspirations of the *Farmer as Doctor* narrative, this technical market-centered narrative adopts an approach that focuses on adjustments within the existing system. It frames microbiome advancements in terms of business opportunities, with language like *"precompetitive benefit"* (I11) and *"compensation"* (I2) reflecting a market-driven mindset. Here, the microbiome serves as a tool to raise consumer awareness and subtly influence market dynamics, where health becomes an added selling point rather than a central paradigm shift (I11).

Despite its incremental focus, the narrative envisions a future where microbiome-friendly farming practices are mainstream (I1), produced sustainably, and enhance food quality from the soil up. Yet significant challenges remain, particularly the high costs of scaling microbiome-based technologies. As one participant notes: *"Imagine if you wanted to cultivate arable land with probiotics, you would need enormous quantities. That is simply too costly"* (I14). In sum, this narrative situates the microbiome within a

market-driven framework, seeking practical solutions that fit within current agricultural and economic systems.

Food as Medicine: integrating agriculture into preventive healthcare

In recent years, healthcare professionals have increasingly acknowledged microbiomes as essential to preventive health, particularly in managing and mitigating chronic illnesses. Nutrient-dense, microbiome-friendly foods are increasingly seen as powerful tools for supporting gut health and overall well-being. Within this narrative, *"Food as Medicine"* (I12) goes beyond being a metaphor to become a structured approach in healthcare. One participant captures this paradigm shift: *"We must also understand that we should not fight against microorganisms but should live in symbiosis with all those microorganisms around us and in our bodies. […] Then you automatically end up with the microbiome of the soil and our food"* (I16). This perspective challenges traditional attitudes, reframing microorganisms from threats to vital allies. It promotes a more holistic view of health, emphasizing symbiosis over eradication and pointing to the interconnectedness of the human microbiome, soil, and food systems.

The narrative also positions the microbiome as a remedy to systemic healthcare challenges, offering a preventive alternative to the current reactive paradigm. As one participant warns: *"We are heading for a Health Disaster in the Netherlands. In 2030 we will even have to start pulling people out of the business world to be able to care for all the sick people. And science has also reached the point where they say, well, 80% of all those illnesses have a clear relationship with nutrition and lifestyle"* (I16). By addressing the root causes of illness through microbiome-supportive diets and lifestyle changes, this approach seeks to lighten the growing strain on healthcare systems. However, it also represents a shift away from pharmaceutical-centric models. As another participant critiques: *"That also has everything to do with the current way in which medicine looks at disease: disease is mainly the presence of symptoms. And the result of that is that especially the pharmaceutical industry is mainly interested in keeping people alive for a very long time, but preferably by continuously giving them medicines to suppress symptoms; then they earn the most"* (I15). The microbiome offers a contrasting vision, prioritizing prevention over symptom management.

Integration of agrifood and healthcare systems is central to this narrative, envisioning dietary interventions as integral to medical care. Future scenarios include "*food pharmacies*,"(I12) where healthcare providers prescribe microbiome-friendly foods alongside medications, potentially supported by insurance coverage (I5). Yet, economic and regulatory challenges complicate implementation. As a participant argues: *"The regulations should be open to the fact that not every micro-organism or composition of micro-organisms should be considered basically unsafe, but actually basically safe"* (I11). These obstacles highlight the need for structural change to fully realize the integrative potential of the microbiome in both health and food systems.

Gut Microbiome for Preventive Health

Economic and technological advancements are positioning the microbiome as a cornerstone of healthcare innovation. Researchers and companies are increasingly pursuing personalized nutrition and gut-health diagnostics, aiming to use individual microbiome profiles to tailor dietary advice, supplements, and probiotics to patients' unique needs. This innovation is supported by new medical technologies that enable monitoring gut health, offering healthcare providers tools to customize preventive and therapeutic care for conditions such as chronic diseases and digestive disorders. One participant envisions a future where microbiome data becomes routine: *"Personalized care is on the horizon. So, a patient goes to the general practitioner. Now, the response is based on blood tests and metadata […], in 10 years microbiome data may also be looked at. The patient will find it increasingly normal to 'hand in a poop'"* (I17). This reflects growing optimism about the microbiome's potential to reshape diagnostics and care delivery.

Despite its promise, this transformation faces skepticism. Public attitudes toward probiotics and Dutch food culture reveal a cautious stance. While the Netherlands excels in microbiome research, its conservative policy environment slows the uptake of innovations. One participant explains: *"The Netherlands is very progressive […] when it comes to microbial research; we simply have the top scientists. […] However, when it comes to innovations […] based on this science […] the Netherlands ranks 22nd or 23rd in Europe. This is opposed to […] countries like Germany, where it's no longer an issue to talk about taking probiotics alongside antibiotic treatment"* (I18). This illustrates the tension between groundbreaking scientific work and the slow integration of such findings into clinical practice. Moreover, the emphasis on randomized controlled trials (RCTs) as the gold standard for evidence creates challenges for validating microbiome-based treatments. As one participant critiques: *"How the microbiome is perceived in the Netherlands is related to the way we look at evidence-based medicine […] And if you consider that the microbiome is an extremely personal thing […] then you can wonder whether that way of conducting research is even possible"* (I14).

While this narrative emphasizes healthcare innovations, its ties to the agrifood sector are limited. The commercialization of high-tech microbiome solutions raises questions about accessibility and equity, as these services remain

prohibitively expensive for many. One participant highlights this concern: *"What does hold me back—and what holds others back—is the price tag attached to it. […] This is not yet covered by the health insurer. That is something that raises the threshold for doing such an analysis"* (I13). Without insurance coverage or regulatory support, these innovations risk being accessible only to wealthier individuals, reinforcing disparities in healthcare.

Microbial Risk and Food Safety

This narrative underscores the dual perception of the microbiome as both an opportunity and a challenge, with its potential health benefits tempered by concerns over food safety. Attitudes toward the microbiome in this context are marked by skepticism, particularly regarding the readiness of scientific evidence to support microbiome-focused dietary innovations. One participant noted, *"It's still too early to be able to base nutritional advice on something that would be going on in the microbiome. This was a discussion already 20 years ago. Well, it hasn't changed all that much"* (I20). This hesitation reflects broader concerns about the complexity of microbial interactions and the lack of robust, actionable insights to integrate microbiome science into everyday practices confidently.

The transformative potential of microbiome-centered healthcare innovations is overshadowed by microbial safety risks. Critics emphasize the lack of clarity surrounding microbiome-based products, particularly in identifying specific strains and understanding their health impacts. As one participant explained, *"It needs to be clear exactly what is in it. If it is not clear how much and which strain [subtype of a microorganism] is present, then it is essentially already worthless."* (I20). This highlights the challenge of establishing the credibility and efficacy of microbiome innovations in the absence of validation processes. Moreover, concerns about unintended consequences, such as exposure to harmful bacteria, further complicate the narrative. As another interviewee remarked, *"Of course also a microbial risk in fact, right? You can also create something because maybe [it's] not safe. And we don't know at all whether it has a health effect at all"* (I20). These fears point to the need for a cautious approach to integrating microbiome advancements into health-related products and services.

In integrating agrifood and health, regulatory and policy frameworks present significant barriers. Microbiome considerations remain peripheral in food policy discussions, with public authorities prioritizing managing microbial risks over leveraging microbiome benefits. One participant observed, *"The microbiome is not a specific subject of such research"* (I24). European regulations focus heavily on controlling microbiological risks. Another participant noted, *"If you look at those European rules, I would argue that the majority of them are focused on controlling microbiological problems"* (I22).

Discussion

Across four of the five narratives, excluding *Microbial Risk and Food Safety*, participants framed the microbiome within a systemic, ecocentric paradigm. Human and ecological health were portrayed as deeply interconnected within broader ecological and societal systems rather than isolated phenomena. One participant explained: "*If the planet Earth is doing bad, you are going to do bad as well*" (I7), capturing the logic of health as a system-level outcome. This symbolic and material alignment between soil and gut was frequently emphasized. One participant observed that the composition of human stool can reflect dietary patterns and, potentially, offer insights into the state of the soil microbiome. (I16), implicitly contesting reductionist paradigms such as "*one germ, one disease, one antibiotic*" (I14). Others described the microbiome as a boundary object that connects actors across sectors: "*It connects different actors ranging from medical doctors to farmers*" (I3), evoking an integrative vision in which soil, plant, and gut microbiomes are co-constitutive.

The *Farmer as Doctor* and *Food as Medicine* narratives stand out for their integrative ambition. Although rooted in different sectors—agrifood and healthcare, respectively—they converge on a vision of systemic transformation centered on microbiome health. The *Farmer as Doctor* narrative is strongly connected to micro-level action, as it reframes farmers as frontline health actors and positions soil microbiomes as foundational to both ecological sustainability and human vitality. "*The soil is the basis of everything, and if we treat it well, we're treating ourselves well too*" (I7), a participant explained. This narrative leans toward deep leverage points, emphasizing care, reciprocity, and ecological responsibility, echoing the views of Sessitsch et al. (2023), who highlight microbial health as key to sustainable agriculture and resilience.

Similarly, the *Food as Medicine* narrative emerges from healthcare actors who promote microbiome-based interventions like dietary changes and personalized nutrition to prevent illness. By framing the microbiome as an ecocentric diagnostic tool, this narrative connects food consumption to agriculture, linking health outcomes to production practices. Olmo et al. (2023) support this link, showing soil restoration can enhance gut health. Despite differing origins, both narratives advocate systemic approaches that center microbiome health for human and planetary well-being. This convergence reflects the kind of interconnected perspective described by Assmuth et al. (2020), who emphasize a socio-ecological understanding of health in which human health,

ecosystem health, and social well-being are interconnected. This argument strengthens the incentive to work beyond disciplinary silos, suggesting that health is not just about nutrition or disease prevention, but about reconfiguring relationships between people, food systems, and the environment.

The other narratives offer an important contrast. *Gut Microbiome for Preventive Health* shares *Food as Medicine*'s focus on prevention but leans on the promise of precision medicine. While potentially transformative, this orientation risks reinforcing individualized understandings of health and neglecting collective or structural determinants. *Soil Microbiome for Agricultural Innovation*, by contrast, emphasizes technological and market-based solutions, targeting shallow leverage points like practices and incentives. These differences illustrate how narratives vary in content, depth, and scale of proposed change.

Together, the narratives span a continuum of leverage points from shallow adjustments in practice to deeper shifts in paradigms. Yet even the most integrative visions remain constrained by sectoral logic, regulatory fragmentation, and institutional silos. Power asymmetries persist, raising the question: who gets to define what a "Healthy Food System" should look like, and on whose terms?

The *Microbial Risk and Food Safety* narrative brings these tensions into focus. Here, microbes are framed as risks requiring control, emphasizing predictability and evidence-based regulation. As one policy actor explained, "*The bulk of European rules are aimed at controlling microbiological problems. […] Food must be safe. There should be no pathogens on food*" (I22). In this framing, microbes remain threats rather than partners in health. Participants noted that the variability and contextuality of microbiome science, "*highly personal, variable, and subject to change over time*" (I14), challenge the creation of standardized knowledge and complicate regulatory action. While this narrative reflects a more established paradigm, its concerns about scientific rigor and public understanding are necessary to be dealt with if microbiome-based approaches are to be institutionalized.

However, many of the emerging, ecocentric narratives rest on scientific uncertainty, assuming a biological continuity between soil, plant, and gut microbiomes that remains only partially substantiated by science. More controlled studies are needed to clarify whether this is a true causal chain or merely a compelling narrative construction. While analogies between ecological and human health may inspire systemic thinking, their empirical basis are still evolving. This calls for critical engagement not only with what these narratives propose, but also with how they are constructed, legitimated, and put into practice.

Narratives driving transformation

Narratives are not neutral. They shape what is thinkable, actionable, and fundable. As Anderson and Rivera-Ferre (2021) argue, they do more than only reflect reality; they structure it. In the case of the microbiome, this structuring power comes into view through narratives that resist dominant logics of extraction, control, and fragmentation. These dominant logics often frame health in a mechanistic terms and food as an input to be optimized (Assmuth et al. 2020; Lobstein 2002). By contrast, microbiome narratives emphasize the interdependence of biological systems, reframing health as an emergent property of balanced ecosystems and microbes as co-inhabitants rather than enemies (Bradford 2020; Paxson and Helmreich 2014). This reframing constitutes more than a scientific insight, it rather functions as a *linguistic* and discursive shift (Cunliffe and Shotter 2013). It represents a reframing of health that invites new understandings of human–environment relations.

This reframing, as articulated by practitioners, positions the microbiome as a boundary object between agrifood and healthcare. In initiatives like Soils2Guts and MicrobiomeSupport,[2] it mobilizes actors across sectors, forming novel actor coalitions that challenge traditional power arrangements (Hajer 1995; Riedy 2020). This positions narratives as means of reconfiguring power, in line with Anderson (2024). Regenerative narratives, she argues, not only reframe problems, but also challenge existing governance structures by legitimizing alternative actors. Therefore, the narratives surrounding the microbiome open up new "solution spaces" and potentially redistribute authority toward farmers, dieticians, or community health actors, figures typically peripheral to institutional healthcare or agricultural policy.

This narrative capacity operates at a deep leverage point in systems thinking. As Meadows (1999) argues, paradigms shape the intent of entire systems, narratives change thus becomes indispensable for system-level transformation. The microbiome operates at this level, by challenging the ontological separation between human and nature, which underlies both industrial agriculture and curative healthcare. This might suggest the early contours of a paradigm shift, as these microbiome narratives begin to shape the conditions for broader institutional and policy change. Waddock (2018) refers to this as "narrative seeds" that (if nurtured) can lead to "systemic resonance". In this light, microbiome initiatives are not marginal experiments, but potential starting points of a broader transformation.

Besides narrative resonance, the microbiome facilitates alignment across sectors. By connecting different themes, ranging from soil degradation, and microbial ecology to

[2] See https://www.microbiomesupport.eu/.

con-communicable diseases, the microbiome offers a shared point of reference. Transformation requires such discursive anchors, enabling the construction of cross-sectoral actor networks (Bodin 2017). In this context, the microbiome acts as a boundary object, flexible enough to be interpreted differently across domains, yet robust enough to hold collective meaning (Klein 2021; Runhaar 2017). This makes it resonate with framework like One Health, which emphasize the interdependence of human, animal, and ecological health (Banerjee and van der Heijden 2023; Ma et al. 2023; WHO 2017).

However, this potential remains contested. Enthusiasm is tempered by a deeply rooted and legitimate narrative that emphasizes microbial risk. Concerns about pathogenic microbes, the complexity of microbial ecosystems, and uncertainty around causal relationships contribute to a more cautious framing. Importantly, the perception of microbes as potential threats is unlikely to ever fully disappear. After all, some microbes cause illness. This reality must be acknowledged and integrated into any combined or integrative narrative, rather than dismissed. This reflects a deeper tension between integrative and risk-oriented paradigms, which is a struggle not just over scientific evidence, but also over questions of legitimacy, precaution, and control. The concept of discourse coalitions (Hajer 1995) is helpful here: opposing networks of actors are held together not just by their institutional roles, but by the narratives they tell. In this light, the microbiome becomes both a bridge and a battleground.

Importantly, the presence of competing narratives should not be seen as failure. The real danger lies in assuming coherence too early (Hajer 2002). While practitioners may embrace the microbiome's promise, institutional uptake remains limited. Transformative framings tend to stay confined to experimental spaces, such as pilot programs, grassroots initiatives, or academic discourse, rather than taking root in mainstream policy (Moore et al. 2015). Without corresponding shifts in funding, regulation, and authority, there is a risk that the narrative's transformative potential remains underrealized, or even co-opted or diluted.

Pathways forward and future research

While the microbiome's potential to generate integrative narratives is evident, the science behind it is still evolving, and these narratives are unfolding within structurally unequal systems that may resist the paradigm shifts they suggest. Future research should therefore address both the rise of these integrative narratives and the institutional conditions that shape their uptake. This includes examining who holds the power and legitimacy to speak for the microbiome and how that authority is constructed; analyzing how precautionary regulatory frameworks may delay or channel microbiome-based innovations; exploring how such interventions might reinforce or challenge existing health inequities; and understanding how various actors adopt or resist microbiome narratives, and with what consequences. In addition, longitudinal research is needed to assess whether microbiome discourse leads to durable institutional change. For now, the microbiome remains a powerful narrative and scientific frontier, but unlocking its transformative potential will demand institutional reconfiguration, and new forms of collaboration.

Conclusion

This study addressed the research question: *What narratives about the microbiome can be identified within agrifood and healthcare systems, and how integrative are these?* It finds that the microbiome serves as a boundary concept for systemic transformation, with five key narratives emerging: *Farmer as Doctor*, *Soil Microbiome for Agricultural Innovation*, *Food as Medicine*, *Gut Microbiome for Preventive Health*, and *Microbial Risk and Food Safety Concerns*.

Among these, the *Farmer as Doctor* and *Food as Medicine* narratives stand out for their integrative potential, framing health as emerging from interconnected ecosystems, promoting socioecological well-being. However, their transformative impact remains underutilized in practice due to systemic barriers such as fragmented policies and sector silos.

In contrast, narratives focused on gut or soil microbiomes often emphasize individual or technological solutions, reinforcing existing paradigms of control and commodification. The risk and safety narrative further prioritizes predictability and standardization, sometimes sidelining ecological perspectives.

Overall, the microbiome discourse reflects a broader shift toward recognizing the interdependence between human and ecological health. As a boundary object, it enables collaboration across sectors, offering common ground for actors from agrifood, healthcare, and environmental science. Its transformative potential lies not only in the scientific insights it carries, but in its ability to mobilize new alliances, shift dominant worldviews, and redefine what is seen as legitimate, desirable, and possible. Yet, this potential is not automatic. It depends on overcoming institutional barriers and creating conditions in which these narrative seeds can be nurtured, scaled and institutionalized in policy and practice. Ultimately, the microbiome's significance extends beyond what it reveals about microbes; it lies in what it allows us to imagine and become in the transformation toward a more integrated and ecological future.

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References

Abson DJ, Fischer J, Leventon J, Newig J, Schomerus T, Vilsmaier U, Von Wehrden H, Abernethy P, Ives CD, Jager NW (2017) Leverage points for sustainability transformation. Ambio 46:30–39

Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, Mullany EC, Abate KH, Abbafati C, Abebe Z (2019) Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 393(10184):1958–1972

Anderson MD (2024) Transforming food systems: narratives of power. Routledge, London. https://doi.org/10.4324/9781003260264

Anderson MD, Rivera-Ferre M (2021) Food system narratives to end hunger: extractive versus regenerative. Curr Opin Environ Sustain 49:18–25

Assmuth T, Chen X, Degeling C, Haahtela T, Irvine KN, Keune H, Kock R, Rantala S, Rüegg S, Vikström S (2020) Integrative concepts and practices of health in transdisciplinary social ecology. Socio-Ecol Pract Res 2:71–90

Banerjee S, van der Heijden MG (2023) Soil microbiomes and One Health. Nat Rev Microbiol 21(1):6–20

Barros-Rodríguez A, Rangseekaew P, Lasudee K, Pathom-Aree W, Manzanera M (2021) Impacts of agriculture on the environment and soil microbial biodiversity. Plants 10(11):2325

Bentz J, O'Brien K, Scoville-Simonds M (2022) Beyond "blah blah blah": exploring the "how" of transformation. Sustain Sci 17(2):497–506

Berg G, Rybakova D, Fischer D, Cernava T, Vergès M-CC, Charles T, Chen X, Cocolin L, Eversole K, Corral GH (2020) Microbiome definition re-visited: old concepts and new challenges. Microbiome 8:1–22

Berzonsky CL, Moser SC (2017) Becoming *Homo sapiens* sapiens: mapping the psycho-cultural transformation in the anthropocene. Anthropocene 20:15–23

Bodin Ö (2017) Collaborative environmental governance: achieving collective action in social–ecological systems. Science 357(6352):eaan1114

Bradford AA-A (2020) Symbiotic grace: holobiont theology in the age of the microbe. Duke University, Durham

Briassoulis H (2005) Policy integration for complex environmental problems: the example of mediterranean desertification, 1st edn. Routledge, London. https://doi.org/10.4324/9781315246598

Brives C, Rest M, Sariola S (2021) With microbes. Mattering Press, Manchester. https://doi.org/10.28938/9781912729180

Candel JJ, Pereira L (2017) Towards integrated food policy: main challenges and steps ahead. Environ Sci Policy 73:89–92

Commission E (2020) Farm to Fork strategy: for a fair, healthy and environmentally-friendly food system

Cunliffe AL, Shotter J (2013) Linguistic artifacts in organizing and managing. In: Artifacts and organizations. Psychology Press, New York, pp 119–138.

Darier E (1999) Foucault against environmental ethics. In: Discourses of the environment. Blackwell Publishers, Oxford, pp 217–240

Daugbjerg C, Feindt PH (2019) Post-exceptionalism in public policy: transforming food and agricultural policy. Transforming food and agricultural policy. Routledge, London, pp 1–20

Daugbjerg C, Feindt PH (2022) Post-exceptionalism in the common agricultural policy. In: Graziano PR, Tosun J (eds) Elgar encyclopedia of European Union Public Policy. Edward Elgar Publishing, Cheltenham, pp 283–291. https://doi.org/10.4337/9781800881112.ch30

Di Cesare M (2019) Global trends of chronic non-communicable diseases risk factors. Eur J Public Health 29(Supplement_4):ckz185.196

Dorninger C, Abson DJ, Apetrei CI, Derwort P, Ives CD, Klaniecki K, Lam DP, Langsenlehner M, Riechers M, Spittler N (2020) Leverage points for sustainability transformation: a review on interventions in food and energy systems. Ecol Econ 171:106570

Ehrenfeld JR (2004) Searching for sustainability: no quick fix. Reflections 5(8):1–13

Erisman JW (2021) Nature-based agriculture for an adequate human microbiome. Org Agric 11(2):225–230

FAO, IFAD, UNICEF, WFP, & WHO. (2023). The State of Food Security and Nutrition in the World 2023 Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum. https://www.fao.org/3/cc3017en/cc3017en.pdf

Federoff HJ, Gostin LO (2009) Evolving from reductionism to holism: is there a future for systems medicine? JAMA 302(9):994–996

Few R, Morchain D, Spear D, Mensah A, Bendapudi R (2017) Transformation, adaptation and development: relating concepts to practice. Palgrave Commun 3(1):1–9

Fiala V, Jacob K, Barnickel C, Feindt PH (2024) Diverging Stories on food system transitions. A qualitative analysis of policy narratives in the public consultation on the European Commission's Farm to Fork Strategy. J Rural Stud 110:103374

Fiandaca MS, Mapstone M, Connors E, Jacobson M, Monuki ES, Malik S, Macciardi F, Federoff HJ (2017) Systems healthcare: a holistic paradigm for tomorrow. BMC Syst Biol 11:1–17

Foucault M, Howard R (1965) Madness and civilization: a history of insanity in the Age of Reason. Tavistock, London

Frąc M, Hannula ES, Bełka M, Salles JF, Jedryczka M (2022) Soil mycobiome in sustainable agriculture. Front Microbiol 13:1033824

Galli F, Prosperi P, Favilli E, D'Amico S, Bartolini F, Brunori G (2020) How can policy processes remove barriers to sustainable food systems in Europe? Contributing to a policy framework for agri-food transitions. Food Policy 96:101871

Hajer MA (1995) The politics of environmental discourse: ecological modernization and the policy process. Clarendon Press, Oxford

Hajer M (2002) Discourse analysis and the study of policy making. Eur Polit Sci 2(1):61–65

Hall PA (1993) Policy paradigms, social learning, and the state: the case of economic policymaking in Britain. Comp Polit 25(3):275–296. https://doi.org/10.2307/422246

Hannula SE, Ma HK, Pérez-Jaramillo JE, Pineda A, Bezemer TM (2020) Structure and ecological function of the soil microbiome affecting plant–soil feedbacks in the presence of a soil-borne pathogen. Environ Microbiol 22(2):660–676

Hogan J, Howlett M (2015) Policy paradigms in theory and practice: discourses, ideas and anomalies in public policy dynamics. Palgrave Macmillan, London

Hoppe R (2010) From "knowledge use" towards "boundary work": sketch of an emerging new agenda for inquiry into science-policy interaction. Knowledge democracy: consequences for science, politics, and media. Springer, Berlin, pp 169–186

Horton R, Beaglehole R, Bonita R, Raeburn J, McKee M, Wall S (2014) From public to planetary health: a manifesto. Lancet 383(9920):847

IPBES (2019) The global assessment report on biodiversity and ecosystem services: summary for policy makers

IPCC (2022) Global warming of 1.5 C: IPCC special report on impacts of global warming of 1.5 C above pre-industrial levels in context of strengthening response to climate change, sustainable development, and efforts to eradicate poverty. Cambridge University Press, Cambridge

Kamel M, Aleya S, Alsubih M, Aleya L (2024) Microbiome dynamics: a paradigm shift in combatting infectious diseases. J Personal Med 14(2):217

Keller R (2024) The history of the discourse concept. The sociology of knowledge approach to discourse: foundations, concepts and tools for a research programme. Springer, Berlin, pp 125–156

Khmelevtsova LE, Sazykin IS, Azhogina TN, Sazykina MA (2022) Influence of agricultural practices on bacterial community of cultivated soils. Agriculture 12(3):371

Klein JT (2021) Beyond interdisciplinarity: boundary work, communication, and collaboration. Oxford University Press, Oxford

Kluge S (2000) Empirically grounded construction of types and typologies in qualitative social research. Forum Qual Sozialforschung Forum Qual Soc Res 1(1). https://doi.org/10.17169/fqs-1.1.1124

Kokkinias K, Pruneski K, Wrighton K, Kelp N (2024) Examination of public perceptions of microbes and microbiomes in the United States reveals insights for science communication. PloS One 19(10):e0312427. https://doi.org/10.1371/journal.pone.0312427

Kuhmonen T (2017) Exposing the attractors of evolving complex adaptive systems by utilising futures images: milestones of the food sustainability journey. Technol Forecast Soc Change 114:214–225. https://doi.org/10.1016/j.techfore.2016.08.015

Lahsen M, Turnhout E (2021) How norms, needs, and power in science obstruct transformations towards sustainability. Environ Res Lett 16(2):025008

Lal R (2009) Soil degradation as a reason for inadequate human nutrition. Food Secur 1:45–57

Lelieveldt H (2023) Food industry influence in collaborative governance: the case of the Dutch prevention agreement on overweight. Food Policy 114:102380

Lindgren E, Harris F, Dangour AD, Gasparatos A, Hiramatsu M, Javadi F, Loken B, Murakami T, Scheelbeek P, Haines A (2018) Sustainable food systems—a health perspective. Sustain Sci 13:1505–1517

Lobstein T (2002) Food policies: a threat to health? Proc Nutr Soc 61(4):579–585

Lübker HM, Abson DJ, Riechers M (2021) Discourses for deep transformation: perceptions of economic growth in two rural communities in Lower Saxony, Germany. Sustain Sci 16:1827–1840

Ma L-C, Zhao H-Q, Wu LB, Liu C (2023) Impacts of the microbiome on human, animal, and environmental health from a one health perspective. Sci One Health 2:100037

Manghi P, Bhosle A, Wang K, Marconi R, Selma-Royo M, Ricci L, Asnicar F, Golzato D, Ma W, Hang D (2024) Coffee consumption is associated with intestinal *Lawsonibacter asaccharolyticus* abundance and prevalence across multiple cohorts. Nat Microbiol 9:3120–3134

Manlosa AO, Schultner J, Dorresteijn I, Fischer J (2019) Leverage points for improving gender equality and human well-being in a smallholder farming context. Sustain Sci 14:529–541

Mantegazza G, Gargari G, Duncan R, Consalez F, Taverniti V, Riso P, Guglielmetti S (2023) Ready-to-eat rocket salads as potential reservoir of bacteria for the human microbiome. Microbiol Spectr. https://doi.org/10.1128/spectrum.02970-22

Meadows D (1999) Leverage points for sustainability transformation. Sustainability Institute. https://donellameadows.org/wp-content/userfiles/Leverage_Points.pdf

Meadows DH (2008) Thinking in systems: a primer. Chelsea Green Publishing, White River Junction, Vermont

Moore M-L, Riddell D, Vocisano D (2015) Scaling Out, Scaling Up, Scaling Deep*: strategies of non-profits in advancing systemic social innovation. Large systems change: an emerging field of transformation and transitions. Routledge, London, pp 67–84

Morriën E, Hannula SE, Snoek LB, Helmsing NR, Zweers H, De Hollander M, Soto RL, Bouffaud M-L, Buée M, Dimmers W (2017) Soil networks become more connected and take up more carbon as nature restoration progresses. Nat Commun 8(1):14349

Neish AS, Pacifici R, Mulle JG, Kraft CS, Stephens DS (2017) The microbiome: current and future view of an ancient paradigm. Future Med 12(10):831–834. https://doi.org/10.2217/fmb-2017-0083

Nishi M, Nishi M, Subramanian SM, Gupta H (2022) Biodiversity-health-sustainability nexus in socio-ecological production landscapes and seascapes (SEPLS), 1st 2022 edn. Springer Nature, Singapore. https://doi.org/10.1007/978-981-16-9893-4

Nissi R, Pälli P (2020) Textual artefacts at the centre of sensemaking: the use of discursive-material resources in constructing joint understanding in organisational workshops. Discourse Stud 22(2):123–145. https://doi.org/10.1177/1461445619893794

O'brien K (2021) You matter more than you think. cCHANGE Press, Oslo

Oels A (2005) Rendering climate change governable: from biopower to advanced liberal government? J Environ Plan Policy Manag 7(3):185–207. https://doi.org/10.1080/15239080500339661

Olmo R, Wetzels SU, Berg G, Cocolin L, Hartmann M, Hugas M, Kostic T, Rattei T, Ruthsatz M, Rybakova D (2023) Food systems microbiome-related educational needs. Microb Biotechnol 16(7):1412–1422

Paxson H, Helmreich S (2014) The perils and promises of microbial abundance: novel natures and model ecosystems, from artisanal cheese to alien seas. Soc Stud Sci 44(2):165–193

Phillips L, Jorgensen MW (2002) Critical discourse analysis. Discourse analysis: as theory and method. Sage Publications Limited, New York

Pineda A, Kaplan I, Hannula SE, Ghanem W, Bezemer TM (2020) Conditioning the soil microbiome through plant–soil feedbacks suppresses an aboveground insect pest. New Phytol 226(2):595–608. https://doi.org/10.1111/nph.16385

Pryor K, Volpp K (2018) Deployment of preventive interventions—time for a paradigm shift. N Engl J Med 378(19):1761–1763

Raposo A, Zandonadi RP, Botelho RBA (2022) Challenging the status quo to shape food systems transformation from a nutritional and food security perspective. Foods 11(4):604. https://doi.org/10.3390/foods11040604

Raworth K (2017) Doughnut economics: seven ways to think like a 21st century economist. Chelsea Green Publishing, White River Junction

Rees T, Bosch T, Douglas AE (2018) How the microbiome challenges our concept of self. PLoS Biol 16(2):e2005358

Riechers M, Pătru-Dușe IA, Balázsi Á (2021) Leverage points to foster human–nature connectedness in cultural landscapes. Ambio 50(9):1670–1680. https://doi.org/10.1007/s13280-021-01504-2

Riedy C (2020) Discourse coalitions for sustainability transformations: common ground and conflict beyond neoliberalism. Curr Opin Environ Sustain 45:100–112
Riedy C, Waddock S (2022) Imagining transformation: change agent narratives of sustainable futures. Futures J Policy Plan Futures Stud 142:103010. https://doi.org/10.1016/j.futures.2022.103010
Roos N, Wahab MA, Chamnan C, Thilsted SH (2006) Understanding the links between agriculture and health. International Food Policy Research Institute, Washington, DC
Runhaar H (2017) Governing the transformation towards 'nature-inclusive' agriculture: insights from the Netherlands. Int J Agric Sustain 15(4):340–349
Saldaña J (2016) The coding manual for qualitative researchers, 3rd edn. SAGE, Newcastle upon Tyne
Sanders D (2023) The struggle for health: medicine and the politics of underdevelopment. Oxford University Press, Oxford
Sessitsch A, Wakelin S, Schloter M, Maguin E, Cernava T, Champomier-Verges M-C, Charles TC, Cotter PD, Ferrocino I, Kriaa A (2023) Microbiome interconnectedness throughout environments with major consequences for healthy people and a healthy planet. Microbiol Mol Biol Rev 87(3):e00212-00222
Skogstad G (1998) Ideas, paradigms and institutions: agricultural exceptionalism in the European Union and the United States. Governance 11(4):463–490
Van Hulst M, Metze T, Dewulf A, De Vries J, Van Bommel S, Van Ostaijen M (2025) Discourse, framing and narrative: three ways of doing critical, interpretive policy analysis. Crit Policy Stud 19(1):74–96
Verhaeghe P (2012) Identiteit. Uitgeverij de Bezige Bij, Amsterdam
Vijay A, Valdes AM (2022) Role of the gut microbiome in chronic diseases: a narrative review. Eur J Clin Nutr 76(4):489–501. https://doi.org/10.1038/s41430-021-00991-6
Vincent O, Feola G (2020) A framework for recognizing diversity beyond capitalism in agri-food systems. J Rural Stud 80:302–313
Voulvoulis N, Giakoumis T, Hunt C, Kioupi V, Petrou N, Souliotis I, Vaghela C (2022) Systems thinking as a paradigm shift for sustainability transformation. Glob Environ Change 75:102544
Waddock S (2018) Narrative, memes, and the prospect of large systems change. Humanistic Manag J 3(1):17–45
Wassermann B, Müller H, Berg G (2019) An apple a day: which bacteria do we eat with organic and conventional apples? Front Microbiol 10:1629. https://doi.org/10.3389/fmicb.2019.01629
Westley F, Carpenter SR, Brock WA, Holling CS, Gunderson LH (2002) Why systems of people and nature are not just social and ecological systems. Island Press, Washington, D.C.
Whipps J, Lewis K, Cooke R (1988) Mycoparasitism and plant disease control. In: Burge M (ed) Fungi biological control systems. Manchester University Press, Manchester, pp 161–187
WHO (2017) One health. Retrieved December from https://www.who.int/news-room/questions-and-answers/item/one-health
WHO (2024) Global spending on health: coping with the pandemic. World Health Organization, Geneva
Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, Garnett T, Tilman D, DeClerck F, Wood A (2019) Food in the anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet 393(10170):447–492
Wojtynia N, van Dijk J, Derks M, Groot Koerkamp PW, Hekkert MP (2021) A new green revolution or agribusiness as usual? Uncovering alignment issues and potential transition complications in agri-food system transitions. Agron Sustain Dev 41:1–20
WWF (2024) Living planet report 2024—a system in Peril
Zywert K (2017) Human health and social–ecological systems change: rethinking health in the Anthropocene. Anthropocene Rev 4(3):216–238