

## Review Article

# Food Systems, Nutrition and Public Health Outcomes: An Integrated Perspective

Anitha S<sup>1</sup>, Shivabasappa Kandkur<sup>2</sup>, Deepa Pujar<sup>3</sup>

<sup>1</sup>Department of Home Science, Krishi Vigyan Kendra (KVK), Chandurayanahalli, Magadi, Ramanagara, India

<sup>2</sup>Department of Agricultural Engineering, College of Agriculture, Karekere, Hassan, India

<sup>3</sup>Department of Horticulture, Krishi Vigyan Kendra (KVK), Chandurayanahalli, Magadi, Ramanagara, India

### Corresponding Author

Anitha S

Email: anithas080@gmail.com

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### Abstract

Food systems encompass the full spectrum of activities and actors involved in the production, processing, distribution, consumption, and disposal of food. Their structure and functioning exert profound influences on dietary patterns, nutritional status, and population health outcomes. In recent decades, global food systems have undergone rapid transformation driven by urbanization, economic growth, technological advancement, and globalization. While these changes have improved food availability and reduced hunger in many regions, they have also contributed to new challenges, including the rising prevalence of obesity, diet-related non-communicable diseases (NCDs), environmental degradation, and persistent inequities in access to nutritious foods. This review provides a comprehensive and integrated analysis of the relationships between food systems, nutrition, and public health outcomes. It examines how different components of food systems shape dietary behaviors and nutritional quality, highlighting both positive contributions and adverse consequences. The paper explores key issues such as the dual burden of malnutrition, the environmental impacts of food production, the role of ultra-processed foods, and the implications of globalization and market dynamics. Particular attention is given to vulnerable populations, whose nutritional outcomes are disproportionately affected by systemic inefficiencies and inequities. The review further discusses policy frameworks and intervention strategies aimed at transforming food systems to support healthier and more sustainable diets. Approaches such as the One Health framework, sustainable dietary guidelines, and multisectoral governance are emphasized as critical for addressing complex and interrelated challenges. Innovations in food technology, supply chain management, and agricultural practices are also examined for their potential to improve both nutritional and environmental outcomes. The paper concludes that achieving optimal public health outcomes requires a holistic transformation of food systems that integrates nutritional goals with environmental sustainability, economic resilience, and social equity. Coordinated action across sectors, supported by evidence-based policies and informed consumer behavior, is essential to ensure that food systems contribute positively to human health and well-being in the long term.

**Keywords:** Food systems; Public health nutrition; Sustainable diets; Malnutrition; Non-communicable diseases; Food security; Ultra-processed foods

## 1. Introduction

Food systems represent a complex network of processes that link agricultural production to human consumption and health outcomes [1]. These systems include multiple stages—primary production, processing, distribution, retail, consumption, and waste management—each of which influences the availability, affordability, and quality of food. Over the past several decades, food systems have experienced significant structural transformations, largely driven by globalization, urbanization, population growth, and technological innovation. While these developments have contributed to increased food production and reduced global hunger rates, they have also introduced new public health and environmental challenges [2]. One of the most significant shifts has been the global nutrition transition, characterized by a move away from traditional diets rich in whole grains, fruits, and vegetables toward diets high in refined carbohydrates, fats, sugars, and ultra-processed foods. This transition has been accompanied by a rise in obesity and diet-related NCDs, including cardiovascular diseases, diabetes, and certain cancers. At the same time, undernutrition and micronutrient deficiencies persist in many low- and middle-income countries, resulting in a dual burden of malnutrition within and across populations. The structure and functioning of food systems play a critical role in shaping these outcomes [3]. Agricultural practices determine the types of foods produced, while supply chains and market dynamics influence food availability and pricing. Food processing and marketing strategies affect dietary choices, often promoting energy-dense, nutrient-poor foods. Socioeconomic factors, including income, education, and urbanization, further mediate access to healthy diets. In addition to their impact on nutrition, food systems are closely linked to environmental sustainability [4]. Agriculture is a major contributor to greenhouse gas emissions, land use change, water consumption, and biodiversity loss. Unsustainable practices not only threaten ecological balance but also undermine the long-term capacity of food systems to provide adequate nutrition. Therefore, addressing public health challenges requires an integrated perspective that considers both nutritional and environmental dimensions. This paper aims to examine the interconnections between food systems, nutrition, and public health outcomes. It provides a critical review of current evidence, identifies key challenges, and explores strategies for transforming food systems to support healthier and more sustainable diets.

## 2. Components of Food Systems and Their Nutritional Implications

Food systems are composed of interconnected components, each of which plays a distinct role in determining dietary patterns and nutritional outcomes. Primary production, including agriculture, livestock, and fisheries, establishes the foundation by determining the diversity and quantity of available foods. Agricultural policies and practices often prioritize staple crops such as wheat, rice, and maize, which can lead to increased caloric availability but may limit dietary diversity if not complemented by the production of fruits, vegetables, and nutrient-rich foods. Food processing and manufacturing significantly influence the nutritional quality of diets. While processing can enhance food safety, shelf life, and accessibility, excessive processing often results in the addition of sugars, salts, and unhealthy fats. The proliferation of ultra-processed foods has been associated with poor dietary quality and increased risk of NCDs [5]. These products are typically energy-dense, low in essential nutrients, and heavily marketed, particularly in urban settings. Distribution and retail systems determine the accessibility and affordability of foods. Modern supply chains, including supermarkets and global trade networks, have improved food availability but can also contribute to the displacement of local food systems and traditional diets. In many low-income settings, limited infrastructure and market access restrict the availability of fresh and nutritious foods, leading to reliance on inexpensive, processed alternatives [6]. Consumption patterns are shaped by cultural preferences, socioeconomic status, education, and marketing influences. Urbanization and changing lifestyles have led to increased demand for convenience foods, often at the expense of nutritional quality. Finally, food waste and loss represent inefficiencies within the system that reduce overall food availability and contribute to environmental degradation.

## 3. Nutrition and Public Health Outcomes

The relationship between food systems and public health is mediated through dietary intake and nutritional status. Adequate nutrition is essential for growth, development, immune function, and overall well-being. However, imbalances in dietary intake—whether due to deficiency or excess—can lead to adverse health outcomes. Undernutrition remains a significant global challenge, particularly in low- and middle-income countries. It includes conditions such as stunting, wasting, and micronutrient deficiencies, which have long-term consequences for physical and cognitive development. Food systems that fail to

**Table 1.** Environmental Impacts of Food Systems and Public Health Linkages

Environmental Component	Key Drivers in Food Systems	Environmental Impact	Public Health Implications
Climate Change	Livestock emissions, fertilizer use, deforestation	Increased greenhouse gases (CH <sub>4</sub> , N <sub>2</sub> O, CO <sub>2</sub> )	Heat stress, food insecurity, disease spread
Land Use	Agricultural expansion, monocropping	Deforestation, biodiversity loss, soil degradation	Reduced food diversity, malnutrition
Water Use	Irrigation, livestock production	Water depletion, scarcity	Limited access to safe water, sanitation issues
Water Pollution	Fertilizers, pesticides, animal waste	Eutrophication, contamination	Waterborne diseases, toxic exposure
Food Waste	Post-harvest losses, consumer waste	Resource inefficiency, emissions	Reduced food availability, economic loss

**Table 2.** Sustainable Practices in Food Systems

Practice	Description	Environmental Benefit	Nutritional/ Public Health Benefit
Agroecology	Diversified, ecological farming systems	Improved soil health, biodiversity conservation	Increased dietary diversity
Climate-Smart Agriculture	Adaptation and mitigation strategies	Reduced emissions, resilience to climate change	Stable food supply
Integrated Farming	Crop-livestock integration	Nutrient recycling, reduced waste	Improved food availability
Conservation Agriculture	Minimal soil disturbance, crop rotation	Soil conservation, water efficiency	Sustainable crop yields
Circular Economy	Waste reuse (e.g., composting, biogas)	Reduced pollution, resource efficiency	Cleaner environment, safer food

provide diverse and nutrient-rich foods contribute to these conditions. Conversely, overnutrition and obesity have become increasingly prevalent, driven by the widespread availability of energy-dense, nutrient-poor foods [7]. These dietary patterns are strongly associated with NCDs, which are now the leading cause of mortality worldwide. The coexistence of undernutrition and overnutrition within the same populations highlights the complexity of food system-related health challenges [8]. Foodborne diseases represent another important public health concern. Contamination of food at various stages of the supply chain can lead to outbreaks of illness, particularly in settings with inadequate food safety infrastructure. Addressing these risks requires comprehensive monitoring and regulation across the entire food system.

#### 4. Environmental Sustainability and Food Systems

Food systems are among the most significant drivers of environmental change, exerting pressure on climate systems, land resources, water availability, and biodiversity. Agricultural production alone contributes substantially to global greenhouse gas emissions through

activities such as crop cultivation, livestock rearing, fertilizer application, and land-use change. Methane emissions from ruminant livestock, nitrous oxide emissions from fertilized soils, and carbon dioxide emissions from deforestation collectively intensify climate change, thereby creating feedback loops that further threaten food production and public health. The environmental sustainability of food systems is therefore not only an ecological concern but also a critical determinant of long-term nutritional security. Land use represents a major dimension of this challenge [9]. Expansion of agricultural land, particularly for monoculture cropping and livestock grazing, has led to widespread deforestation and habitat loss. This transformation reduces biodiversity, disrupts ecosystem services, and contributes to soil degradation. Intensive farming practices often result in soil erosion, nutrient depletion, and reduced organic matter, undermining the productivity and resilience of agricultural systems. Sustainable land management practices, including agroecology, crop diversification, and conservation agriculture, are essential for restoring soil health and maintaining ecosystem balance. Water resources are equally affected by food system activities. Agriculture accounts for a substantial proportion of global freshwater use,

**Table 3.** Policy Instruments for Food System Transformation

Policy Instrument	Description	Target Area	Expected Outcome
Agricultural Subsidies Reform	Shift support to nutrient-rich crops	Production	Improved dietary diversity
Food Labeling	Front-of-pack nutrition information	Consumption	Healthier food choices
Fiscal Policies	Taxes on sugar, subsidies on healthy foods	Market behavior	Reduced NCD prevalence
Marketing Regulations	Restrict unhealthy food advertising	Consumer protection	Improved child nutrition
Food Safety Standards	Monitoring contaminants and hygiene	Supply chain	Reduced foodborne diseases

**Table 4.** Governance Approaches in Food Systems

Governance Approach	Key Features	Strengths	Challenges
Multisectoral Governance	Coordination across sectors	Holistic policy integration	Institutional complexity
One Health Approach	Integration of human, animal, environmental health	Comprehensive risk management	Requires strong coordination
Community-Based Governance	Local participation and decision-making	Context-specific solutions	Limited scalability
Global Governance	International guidelines and agreements	Standardization, resource mobilization	Implementation gaps
Public-Private Partnerships	Collaboration with industry	Innovation, investment	Conflict of interest risks

particularly in irrigated cropping systems. Unsustainable water extraction can lead to depletion of aquifers, reduced river flows, and increased competition among sectors. Additionally, agricultural runoff containing fertilizers, pesticides, and animal waste contributes to water pollution, causing eutrophication and degradation of aquatic ecosystems [10-11]. These environmental impacts have direct and indirect consequences for human health, including reduced access to clean drinking water and increased exposure to contaminants. Another concern is food loss and waste, which represents inefficiency across the food system. A significant proportion of food produced is lost during production, storage, transportation, and consumption stages. This not only reduces food availability but also results in unnecessary use of natural resources and increased greenhouse gas emissions. Addressing food waste through improved infrastructure, storage technologies, and consumer awareness is a key strategy for enhancing sustainability [12-13]. The concept of sustainable food systems emphasizes the need to balance environmental integrity with food production goals. This involves adopting practices that reduce emissions, conserve natural resources, and enhance resilience to climate change. Approaches such as climate-smart agriculture, integrated farming systems, and circular resource management offer promising pathways for

achieving these objectives. By aligning environmental sustainability with nutritional outcomes, food systems can be transformed into engines of both ecological and human well-being.

## 5. Policy and Governance

Policy and governance frameworks play a central role in shaping food systems and determining their impact on nutrition and public health. Governments influence food systems through a wide range of mechanisms, including agricultural subsidies, trade policies, food safety regulations, and public health interventions [14-15]. The effectiveness of these policies depends on their ability to address the interconnected nature of food systems while balancing competing objectives such as economic growth, environmental sustainability, and population health. Agricultural policies have historically prioritized the production of staple crops to ensure food security, often at the expense of dietary diversity and nutritional quality. While such approaches have been successful in increasing caloric availability, they have not adequately addressed micronutrient deficiencies or the rising prevalence of diet-related non-communicable diseases. There is growing recognition of the need for nutrition-sensitive agricultural policies that promote the production of diverse, nutrient-rich foods, including fruits, vegetables, legumes, and

animal-source products. Regulatory measures targeting the food industry are also critical. Policies such as front-of-pack nutrition labeling, taxation of sugar-sweetened beverages, restrictions on trans fats, and limits on marketing of unhealthy foods—particularly to children—have been implemented in various countries to improve dietary patterns. These interventions aim to create healthier food environments by influencing both consumer behavior and industry practices [16-17]. However, their effectiveness depends on strong enforcement mechanisms and public acceptance. Food safety governance is another essential component. Ensuring the safety and quality of food across the supply chain requires robust regulatory systems, effective monitoring, and adherence to international standards. Foodborne diseases remain a significant public health burden, particularly in low-resource settings where infrastructure and regulatory capacity may be limited. Strengthening food safety systems not only protects consumer health but also enhances confidence in food markets and facilitates trade. Multisectoral governance is for addressing the complex challenges associated with food systems. Nutrition and public health outcomes are influenced by policies across multiple sectors, including agriculture, health, environment, education, and trade. Coordinated action among these sectors is necessary to ensure policy coherence and avoid unintended consequences. The One Health approach provides a valuable framework for integrating human, animal, and environmental health considerations into policy development and implementation. In addition to national policies, global governance mechanisms play an important role. International organizations and agreements influence food systems through guidelines, standards, and funding initiatives [18]. Achieving meaningful transformation requires alignment between global and local priorities, as well as active participation from diverse stakeholders, including governments, private sector actors, civil society, and communities.

## 6. Innovations and Future Directions

Innovation is a key driver of transformation in food systems, offering opportunities to address the intertwined challenges of nutrition, public health, and environmental sustainability. Advances in agricultural technologies, food processing, and supply chain management are reshaping how food is produced, distributed, and consumed. These innovations have the potential to enhance efficiency, reduce environmental impacts, and improve access to nutritious foods [19]. One of the most significant areas of innovation is precision agriculture, which utilizes digital technologies such as

sensors, satellite imagery, and data analytics to optimize resource use and increase productivity. Precision farming enables farmers to apply inputs such as water, fertilizers, and pesticides more efficiently, reducing waste and environmental harm. In livestock systems, precision technologies facilitate real-time monitoring of animal health and productivity, contributing to improved welfare and reduced disease risks. Biotechnological advancements are also playing a role in enhancing food system resilience. Genetic improvement of crops and livestock can increase resistance to diseases, pests, and environmental stressors, thereby improving yields and reducing reliance on chemical inputs. Biofortification of staple crops with essential micronutrients offers a promising strategy for addressing hidden hunger in populations with limited dietary diversity. The development of alternative protein sources represents another in food system innovation. Plant-based proteins, cultured meat, and insect-based foods are gaining attention as sustainable alternatives to conventional animal-source foods. These options have the potential to reduce greenhouse gas emissions, land use, and water consumption while meeting growing global protein demand [20]. However, their scalability, affordability, and consumer acceptance remain key challenges. Supply chain innovations are equally important. Improvements in storage, transportation, and logistics can significantly reduce food loss and waste, enhancing overall system efficiency. Cold chain technologies, digital marketplaces, and blockchain-based traceability systems contribute to better food quality, safety, and transparency. These developments are particularly relevant in low- and middle-income countries, where infrastructure limitations often hinder access to fresh and nutritious foods. Consumer-focused innovations, including digital health tools, nutrition education platforms, and behavioral interventions, are also shaping dietary patterns [21-23]. Increasing awareness of the links between diet, health, and sustainability can influence consumer choices and drive demand for healthier and more sustainable food options. At the same time, policy support and market incentives are necessary to ensure that such innovations are accessible and equitable, the successful integration of these innovations into food systems will depend on supportive policy environments, investment in research and development, and effective knowledge transfer. Collaboration among governments, academia, industry, and civil society is essential to scale up promising solutions and ensure that they contribute to improved nutrition and public health outcomes.

**Table 5.** Innovations in Food Systems and Their Impacts

Innovation Type	Example	Key Benefits	Limitations
Precision Agriculture	Sensors, AI-based farming	Resource efficiency, higher yields	High initial cost
Biotechnology	Biofortified crops	Improved nutritional value	Regulatory concerns
Alternative Proteins	Plant-based, cultured meat	Lower environmental footprint	Consumer acceptance
Supply Chain Technology	Cold chains, blockchain	Reduced food loss, improved safety	Infrastructure requirements
Digital Nutrition Tools	Apps, e-health platforms	Behavior change, awareness	Digital divide

**Table 6.** Barriers and Opportunities in Food System Transformation

Category	Barriers	Opportunities
Economic	High cost of sustainable technologies	Green investments, subsidies
Social	Cultural resistance to dietary change	Nutrition education, awareness
Environmental	Climate variability	Climate-resilient agriculture
Technological	Limited access in low-income regions	Digital innovation expansion
Policy	Fragmented governance	Integrated policy frameworks

## 7. Discussion

The interrelationships between food systems, nutrition, and public health outcomes are complex, dynamic, and context-specific, requiring a systems-oriented analytical framework. Food systems simultaneously function as determinants of dietary intake, drivers of environmental change, and engines of economic activity. Consequently, interventions targeting a single component often generate ripple effects across multiple domains. This interconnectedness underscores the necessity of integrated approaches that account for trade-offs, synergies, and feedback mechanisms within the system [24]. A central issue in this discourse is the coexistence of undernutrition and overnutrition, commonly referred to as the dual burden of malnutrition. In many low- and middle-income countries, rapid urbanization and economic transitions have led to increased availability of inexpensive, energy-dense foods, while access to diverse and nutrient-rich foods remains limited. As a result, populations experience persistent micronutrient deficiencies alongside rising rates of obesity and diet-related non-communicable diseases (NCDs) [25]. This paradox reflects structural inefficiencies within food systems, including imbalanced agricultural priorities, inequitable distribution networks, and aggressive marketing of ultra-processed foods. Socioeconomic inequalities further exacerbate disparities in nutritional outcomes. Income, education, and geographic location significantly influence access to healthy diets. Vulnerable populations, particularly those in rural or marginalized urban settings, often face barriers such as high food prices, limited availability of fresh produce, and inadequate infrastructure. These

constraints contribute to dietary patterns that are sub-optimal in both quality and diversity [26]. Addressing these inequities requires targeted interventions, including social protection programs, improved market access, and investments in local food systems. Another critical dimension is the environmental sustainability of food systems. Current production practices, particularly those associated with intensive agriculture and livestock systems, contribute to greenhouse gas emissions, land degradation, and water scarcity. These environmental pressures not only threaten ecosystem health but also compromise the long-term capacity of food systems to provide adequate nutrition. Climate change further amplifies these challenges by affecting crop yields, food prices, and the stability of supply chains. Therefore, aligning nutritional objectives with environmental sustainability is essential for ensuring resilience and long-term food security. Consumer behavior and dietary choices represent an important leverage point for transformation. Food preferences are shaped by cultural norms, marketing influences, and socioeconomic factors. The widespread availability and affordability of ultra-processed foods have shifted consumption patterns toward diets that are high in sugars, fats, and salt. Public health interventions aimed at modifying consumer behavior—such as nutrition education, front-of-pack labeling, and fiscal policies—can play a significant role in promoting healthier diets [27]. However, such interventions must be complemented by structural changes within the food system to ensure that healthy choices are accessible, affordable, and culturally acceptable. Governance and institutional frameworks are equally in shaping food systems. Effective policies must be co-

**Table 7.** Linkages Between Food Systems, Diets, and Health Outcomes

Food System Factor	Dietary Impact	Health Outcome
Increased ultra-processed foods	High sugar, fat, salt intake	Obesity, diabetes, CVDs
Limited food diversity	Nutrient deficiencies	Stunting, anemia
High animal-source food intake (excess)	Saturated fat consumption	Cardiovascular diseases
Improved food access	Balanced diets	Better overall health
Food contamination	Unsafe consumption	Foodborne illnesses

herent, evidence-based, and aligned across sectors, including agriculture, health, trade, and environment. Fragmented or inconsistent policies can undermine efforts to improve nutrition and sustainability. Multi-sectoral coordination, supported by robust monitoring and evaluation mechanisms, is essential for achieving policy coherence and accountability [28-31]. The integration of the One Health approach provides a valuable framework for addressing cross-cutting issues such as food safety, zoonotic diseases, and antimicrobial resistance. Despite increasing recognition of these challenges, several barriers to transformation persist. These include limited financial resources, technological constraints, resistance from vested interests, and gaps in data and research. Smallholder farmers, who play a crucial role in food production in many regions, often lack access to modern technologies, credit, and extension services. Bridging these gaps requires sustained investment, capacity building, and inclusive policies that empower all stakeholders within the food system, the discussion highlights the need for a holistic and coordinated approach to food system transformation. Addressing the multifaceted challenges of nutrition and public health requires interventions that operate across the entire system, from production to consumption, while simultaneously considering environmental sustainability and social equity.

## 8. Conclusion

Food systems are fundamental determinants of population health, shaping dietary patterns, nutritional status, and the prevalence of both communicable and non-communicable diseases. The evidence reviewed in this paper demonstrates that while modern food systems have significantly improved food availability, they have also contributed to a range of public health and environmental challenges. These include the persistence of undernutrition, the rise of obesity and diet-related NCDs, and the degradation of natural resources essential for food production. Transforming food systems to support optimal health outcomes requires a paradigm shift toward integrated, sustainable, and equitable approaches. Such transformation must prioritize the production and consumption of diverse, nutrient-rich foods while reducing reliance on

ultra-processed and environmentally intensive products. This involves reorienting agricultural policies to support diversified production systems, strengthening food supply chains to improve access to healthy foods, and implementing regulatory measures that promote healthier consumer choices. The role of governance is central to this transformation. Policymakers must adopt multisectoral strategies that align objectives across agriculture, health, environment, and trade sectors. Evidence-based interventions, including fiscal policies, food labeling regulations, and public awareness campaigns, are essential for influencing both supply and demand dynamics. At the same time, investments in research, innovation, and infrastructure are necessary to support sustainable production practices and efficient distribution systems. Equity considerations must remain at the forefront of food system transformation efforts. Ensuring that all populations—particularly vulnerable and marginalized groups—have access to safe, affordable, and nutritious food is a fundamental public health priority. Social protection programs, targeted nutrition interventions, and support for smallholder farmers can help address disparities and promote inclusive development, the integration of sustainability principles into food systems offers a pathway toward achieving multiple global objectives, including improved health outcomes, environmental conservation, and economic resilience. Innovations in technology, alternative protein sources, and circular economy models hold promise for reducing the environmental footprint of food production while maintaining nutritional adequacy, an integrated perspective that recognizes the interdependence of food systems, nutrition, and public health is essential for addressing current and future challenges. Coordinated action among governments, industry, academia, and civil society is required to create food systems that are not only productive but also health-promoting, sustainable, and equitable. Such transformation is critical for ensuring the well-being of present and future generations.

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