

UNRAVELLING THE FOOD-HEALTH NEXUS

ADDRESSING PRACTICES, POLITICAL
ECONOMY, AND POWER RELATIONS
TO BUILD HEALTHIER FOOD SYSTEMS

OCTOBER 2017



DISCLAIMER

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SUGGESTION FOR REFERENCING

IPES-Food. 2017. Unravelling the Food–Health Nexus: Addressing practices, political economy, and power relations to build healthier food systems. The Global Alliance for the Future of Food and IPES-Food.

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ACKNOWLEDGEMENTS

The Global Alliance for the Future of Food and IPES-Food would like to gratefully acknowledge the many people involved in the preparation of this report. First and foremost, the Global Alliance thanks IPES-Food for sharing the breadth and depth of their collective expertise throughout the development of the report, and for partnering with us to grapple with the complexity of the Food–Health Nexus. In particular, we would like to thank Cecilia Rocha, lead coordinating author, and Nick Jacobs, editorial lead and IPES-Food Coordinator, for their extensive research, expertise, experience, and time. We would also like to thank the IPES-Food working group members for their tireless and valuable contributions throughout the process. We join the authors in thanking Janina Grabs for her valuable and extensive research contributions to all parts of the report, and in thanking Roni Neff for her expert insights through the process; thanks also go to Anna Savelyeva for research support, to students in the 2015–2016 Masters program in Food Security at the Roma Tre University, and research assistants at Ryerson University. We would also like to thank the reviewers who provided valuable perspectives and insights at early stages of the report’s development. The Global Alliance’s Advancing Well-being Working Group must be acknowledged for its guidance in the development of this report. Its commitment to realizing a health-focused food system is impressive and critical — a commitment felt and appreciated throughout the process. We extend deep gratitude to Global Alliance consultants: Lauren Baker for providing project management and editorial oversight; Zanele Sibanda for operational support; and, Alex Kollo for communications and distribution. Studio:Blackwell provided the design and layout of the final publication, and Hypenotic designed the graphic elements and accompanying infographic. This report is all the stronger due to their professional hands in helping to shape its form and content from beginning to end.

ABOUT IPES-FOOD

The International Panel of Experts on Sustainable Food Systems (IPES-Food), established in 2014, seeks to inform debates on food systems reform through policy-oriented research and direct engagement with policy processes around the world. The expert panel brings together environmental scientists, development economists, nutritionists, agronomists, and sociologists, as well as experienced practitioners from civil society and social movements. The panel is co-chaired by Olivier De Schutter, former UN Special Rapporteur on the Right to Food, and Olivia Yambi, nutritionist and former UNICEF representative to Kenya. IPES-Food employs a holistic food systems lens and focuses on the political economy of food systems, i.e., the differential power of actors to influence priority-setting and decision-making.



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ABOUT THE GLOBAL ALLIANCE FOR THE FUTURE OF FOOD

The Global Alliance for the Future of Food cultivates healthy, equitable, renewable, resilient, and culturally diverse food and agriculture systems shaped by people, communities, and their institutions.

We are a unique collaboration of philanthropic foundations that have come together to strategically leverage resources and knowledge, develop frameworks and pathways for change, and push the agenda for more sustainable food and agriculture systems globally. Representing countries across the globe — with diverse interests and expertise spanning health, agriculture, food, conservation, cultural diversity, and community well-being — the Global Alliance shares a belief in the urgency of advancing sustainable global agriculture and food systems, and in the power of working together and with others to effect positive change.



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FOREWORD

Good food is a cornerstone of good health, and this fundamental relationship is widely understood. Yet profound changes in global food systems over the last decades have resulted in significant negative impacts on health and well-being that range from food insecurity to chronic disease, and from environmental degradation to diminished economic opportunity and the erosion of culture. These impacts are experienced unequally across the globe and between different groups of people in different places.

Transformational change is needed. At the Global Alliance for the Future of Food we believe that health and well-being are central to sustainable food systems that are renewable, resilient, equitable, healthy, diverse, and interconnected. We are a strategic alliance of mostly private foundations working together and with others to transform global food systems now and for future generations. As such, we have the privilege, the responsibility, and the opportunity to make the impact of food systems on health and well-being more visible to decision makers, and to strengthen the fundamental role that food systems play in creating and sustaining health and well-being in all communities and populations. We commissioned this report from the International Panel of Experts on Sustainable Food Systems (IPES-Food) as one contribution to this shared goal.

In the report, IPES-Food — an independent panel of food systems experts — assesses the negative health impacts of food systems and explains how these systems are locked into cycles that produce poor health. The members of IPES-Food brought their collective wisdom and diverse perspectives to this challenge, outlining the unacceptable harm caused by our current food systems, and calling for precaution, prevention, and collective action. The Global Alliance for the Future of Food worked closely with IPES-Food to: understand the broad range of evidence that informs the report's findings; analyze how and why food systems are making people sick; expose the health costs externalized by the food system; understand how to internalize these costs through healthier food systems practices and explore potential levers for change.

The report's findings are startling and difficult to ignore. Multiple channels across food systems threaten human health. The resulting health impacts are severe, but are rarely examined together, systematically. Each impact appears as discrete and unrelated to the next, but through a systems view their interrelationships, linkages, and complex associations are revealed. The health impacts of food systems disproportionately affect the most vulnerable in our communities, and are compounded by climate change, poverty, inequality, poor sanitation, and the prevalent disconnect between food production and consumption. The true costs of these impacts are staggering.

The Global Alliance is deeply interested in the evidence challenges explored by IPES-Food in this report. When viewed holistically, the diverse evidence available about the health impacts of food systems points to an urgent need for fundamental change. Collective action can be catalyzed not only by improving the development of scientific evidence, but also by bridging diverse experience and knowledge of the health impacts of food systems to better understand the problems and generate creative solutions.

We at the Global Alliance are interested in working with others to understand how we can break the cycles that produce negative health impacts and catalyze positive change. The report identifies five levers that support rebuilding food systems on new and healthier foundations:

1. Promoting food systems thinking

How do we build our understanding of the food system’s complexity while working to shift the system to generate health and well-being for people and communities globally?

2. Reasserting scientific integrity and research as a public good

How do we make the evidence that connects food systems to health and well-being more transparent, ensure it is visible by decision makers, and move from the current narrow range of outcome indicators towards more holistic indicators such as nutrition, health, happiness, and social and cultural well-being?

3. Bringing the alternatives to light

How can the broad array of practices and positive pathways that connect food systems to ecology and health that are being developed across multiple sectors be supported and promoted?

4. Adopting the precautionary principle

How do we retool food systems to take an “upstream” public health approach that addresses the ecological, social, and cultural determinants of health?

5. Building integrated food policies under participatory governance

How do we collectively integrate broad, multi-sectoral, and long-term understandings of the multiple ways that food systems affect well-being into government policy and private sector decisions?

We believe that food systems that advance long-term health and well-being are essential. Truly healthy food systems will be built on a more integrated, multi-faceted, and holistic approach including nutrition, health, happiness, and social and cultural indicators interpreted together and in relation to each other within the context of healthy and well-functioning food and agricultural systems. And truly healthy food systems will take as their starting point a preventative, precautionary approach, triggering a shift from systems that result in harm to systems that are based on prevention and health promotion.

To create a food system that advances well-being will require global dialogue and action, coordination across multiple sectors that do not ordinarily work together, attention to local and global equity and cultural life-ways, and a strategic focus on systemic solutions and policy opportunities to support sustainable change. This report is an important step towards a much-needed global dialogue on putting health at the centre of food systems.

Working collectively to create a food system that produces health and wellness is a shared responsibility upon which we, as a global community, simply must act. The Global Alliance for the Future of Food is committed to engaging with diverse stakeholders — the private sector, government, policymakers, civil society, researchers, food system workers, citizens, and farmers — to better understand the health impacts of food systems, address the most harmful practices, and find new pathways forward, together.

For the future of food,



A handwritten signature in black ink that reads "Ruth Richardson".

RUTH RICHARDSON
Executive Director

KEY MESSAGES

- 1. Alongside many positive impacts, our food systems have increasingly affected health through multiple, interconnected pathways, generating severe human and economic costs.** People get sick because: 1) they work under unhealthy conditions; 2) they are exposed to contaminants in the water, soil, and air; 3) they eat certain unsafe or contaminated foods; 4) they have unhealthy diets; and, 5) they can't access adequate and acceptable food at all times.
- 2. An urgent case for reforming food and farming systems can be made on the grounds of protecting human health.** Many of the most severe health impacts of food systems trace back to some of the core industrial food and farming practices, e.g., chemical-intensive agriculture; intensive livestock production; the mass production and mass marketing of ultra-processed foods; and the development of long and deregulated global commodity supply chains.
- 3. The health impacts of food systems are interconnected, self-reinforcing, and complex — but we know enough to act.** Food systems impacts are caused by many agents, and interact with factors like climate change, unsanitary conditions, and poverty — which are themselves shaped by food and farming systems. This complexity is real and challenging, but should not be an excuse for inaction.
- 4. The low power and visibility of those most affected by food systems jeopardizes a complete understanding of the health impacts, leaving major blind spots in the evidence base.** The precarious working conditions across global food systems create a situation in which those exposed to the greatest health risks are not seen or heard. These blind spots make it less likely for problems to be prioritized politically and allow health risks to continue to afflict marginalized populations.
- 5. Power — to achieve visibility, frame narratives, set the terms of debate, and influence policy — is at the heart of the food–health nexus.** The industrial food and farming model that systematically generates negative health impacts also generates highly unequal power relations. This allows powerful actors including the private sector, governments, donors, and others to set the terms of debate. The prevailing solutions obscure the social and environmental fallout of industrial food systems, leaving the root causes of poor health unaddressed and reinforcing existing social-health inequalities.
- 6. Urgent steps are required to reform food systems practices, and to transform the ways in which knowledge is gathered and transmitted, understandings are forged, and priorities are set.** Silos in science and policy mirror one another. Governance and knowledge structures are currently ill-adapted to address the systemic and interconnected risks emerging from food systems. Steps to build a healthy science-policy interface may be just as important as steps to reform food systems practices.
- 7. The evidence on food systems impacts must continue to grow, but a new basis is required for reading, interpreting, and acting on that evidence in all of its complexity.** The basis for action must increasingly be informed by a diversity of actors, sources of knowledge and disciplines, and by the collective strength, consistency, plausibility, and coherence of the evidence base.
- 8. Five co-dependent leverage points can be identified for building healthier food systems:**
 - 1) promoting food systems thinking at all levels; 2) reasserting scientific integrity and research as a public good; 3) bringing the positive impacts of alternative food systems to light; 4) adopting the precautionary principle; and, 5) building integrated food policies under participatory governance.
- 9. The monumental task of building healthier food systems requires more democratic and more integrated ways of managing risk and governing food systems.** A range of actors — policymakers, big and small private sector firms, healthcare providers, environmental groups, consumers' and health advocates, farmers, agri-food workers, and citizens — must collaborate and share responsibility in this endeavour.



EXECUTIVE SUMMARY

UNRAVELLING THE FOOD-HEALTH NEXUS

Addressing practices, political economy, and power relations to build healthier food systems

Food systems affect health through multiple, interconnected pathways, generating severe human and economic costs. However, the full picture is often lost from view, allowing the connections to be obscured and the root causes of poor health to be left unaddressed. Too often the negative health impacts are disconnected 1) from one another, 2) from the food systems practices that systematically generate health risks, and 3) from the underlying environmental and socio-economic conditions for health — conditions that are, in turn, undermined by food systems activities. This report seeks to provide a comprehensive overview, identifying the multiple, interconnected ways in which food systems affect human health, and how the prevailing power relations and imperatives in food systems help to shape our understanding of the impacts they generate. In other words, the report asks why evidence gaps persist, why negative impacts are systematically reproduced, and why certain problems are not politically prioritized.

The report identifies five key channels through which food systems impact health:

1. Occupational hazards. Physical and mental health impacts suffered by farmers, agricultural labourers, and other food chain workers as a result of exposure to health risks in the field/factory/workplace (e.g., acute and chronic pesticide exposure risks, production line injuries, livelihood stresses). *People get sick because they work under unhealthy conditions.*

2. Environmental contamination. Health impacts arising via the exposure of whole populations to contaminated environments “downstream” of food production, via pollution of soil, air, and water resources or exposure to livestock-based pathogens (e.g., contamination of drinking water with nitrates, agriculture-based air pollution, antimicrobial resistance). *People get sick because of contaminants in the water, soil, or air.*

3. Contaminated, unsafe, and altered foods. Illnesses arising from the ingestion of foods containing various pathogens (i.e., foodborne disease) and risks arising from compositionally altered and novel foods (e.g., nano-particles). *People get sick because specific foods they eat are unsafe for consumption.*

4. Unhealthy dietary patterns. Impacts occurring through consumption of specific foods or groups of foods with problematic health profiles (e.g., resulting in obesity and non-communicable diseases including diabetes, heart disease, cancers). These impacts affect people directly through their dietary habits, which are shaped by the food environment. *People get sick because they have unhealthy diets.*

5. Food insecurity. Impacts occurring through insufficient or precarious access to food that is culturally acceptable and nutritious (e.g., hunger, micronutrient deficiency). *People get sick because they can't access adequate, acceptable food at all times.*

An extensive review of the evidence on these impacts showed that:

An urgent case for reforming food and farming systems can be made on the grounds of protecting human health. The health impacts generated by food systems are severe, widespread, and closely linked to industrial food and farming practices. These impacts are not limited to isolated pockets of

unregulated production in specific locations, or to those excluded from the benefits of modern agriculture and global commodity supply chains. Many of the most severe health impacts trace back to some of the core industrial food and farming practices, e.g., chemical-intensive agriculture; intensive livestock production; the mass production and mass marketing of ultra-processed foods; and, the development of long and deregulated global commodity supply chains. The scope, severity, and cost of these impacts suggests that historical progress in tackling problems like hunger, foodborne illness, and workplace injury may be slowing or even unravelling, while a range of additional disease, contamination, and diet-related risks are emerging fast. The industrial food and farming model does not bear the entire burden for these problems, but has clearly failed to provide a recipe for addressing them individually or collectively.

The health impacts of food systems are interconnected, self-reinforcing, and complex — but we know enough to act. Food systems impacts are caused by many agents, and interact with factors like climate change, unsanitary conditions, and poverty — which are themselves shaped by food and farming systems. Several of these impacts reinforce one another. For example, the stress generated by high-pressure industrialized food-processing plants increases the risks of physical injury; pre-existing disease burdens make people more vulnerable to food insecurity. In other cases, risks tend to accrue across a range of food systems activities and over long periods of time. For example, chronic exposure to Endocrine Disrupting Chemicals (EDCs) is particularly hard to trace to specific sources or even to specific chemicals, while zoonotic pathogens and antimicrobial resistance can spread through multiple pathways within and around food systems. This complexity is real and challenging, but should not be an excuse for inaction.

The low power and visibility of those most affected by food systems jeopardizes a complete understanding of the health impacts, leaving major blind spots in the evidence base. The precarious working conditions across global food systems create a situation in which those exposed to the greatest health risks are not seen or heard. In particular, the insecure status of hired and migrant labourers undermines the reporting of abuses and injuries. Risks to farmers and farmworkers in developing countries are particularly under-documented. These blind spots make it less likely for problems to be prioritized politically, and allow health risks to continue to afflict marginalized populations. This is compounded by a broader disconnection of the general public from the process of food production. Reconnecting people with the realities of the food they eat — and bringing the true cost of our food systems to light — is therefore essential to unlock the food–health nexus.

Power — to achieve visibility, frame narratives, set the terms of debate, and influence policy — is at the heart of the food–health nexus. Powerful actors, including private sector, governments, donors, and others with influence, sit at the heart of the food–health nexus, generating narratives, imperatives, and power relations that help to obscure its social and environmental fallout. Prevailing solutions leave the root causes of poor health unaddressed and reinforce existing social-health inequalities. These solutions, premised on further industrialization of food systems, grant an increasingly central role to those with the technological capacity and economies of scale to generate data, assess risks, and deliver key health fixes (e.g., biofortification, highly traceable and biosecure supply chains). The role of industrial food and farming systems in driving health risks (e.g., by perpetuating poverty and climate change) is left unaddressed. As well, those most affected by the health impacts in food systems (e.g., small-scale farmers in the Global South) become increasingly marginal in diagnosing the problems and identifying the solutions.

Urgent steps are required to reform food systems practices, and to transform the ways in which knowledge is gathered and transmitted, understandings are forged, and priorities are set. Current approaches are locked in across food systems. Silos in science and policy mirror one another. Governance and knowledge structures — reflecting long-standing priorities and path dependencies — are ill-adapted to address the systemic and interconnected risks emerging from food systems. This keeps systemic alternatives off the table and outside of mainstream science-policy debates. Steps to build a healthy science-policy interface may be just as important as steps to reform food systems practices — and may be a condition for reforms to occur.

The evidence on food systems impacts must continue to grow, but we need a new basis for reading, interpreting, and acting on that evidence in all of its complexity. The basis for action must

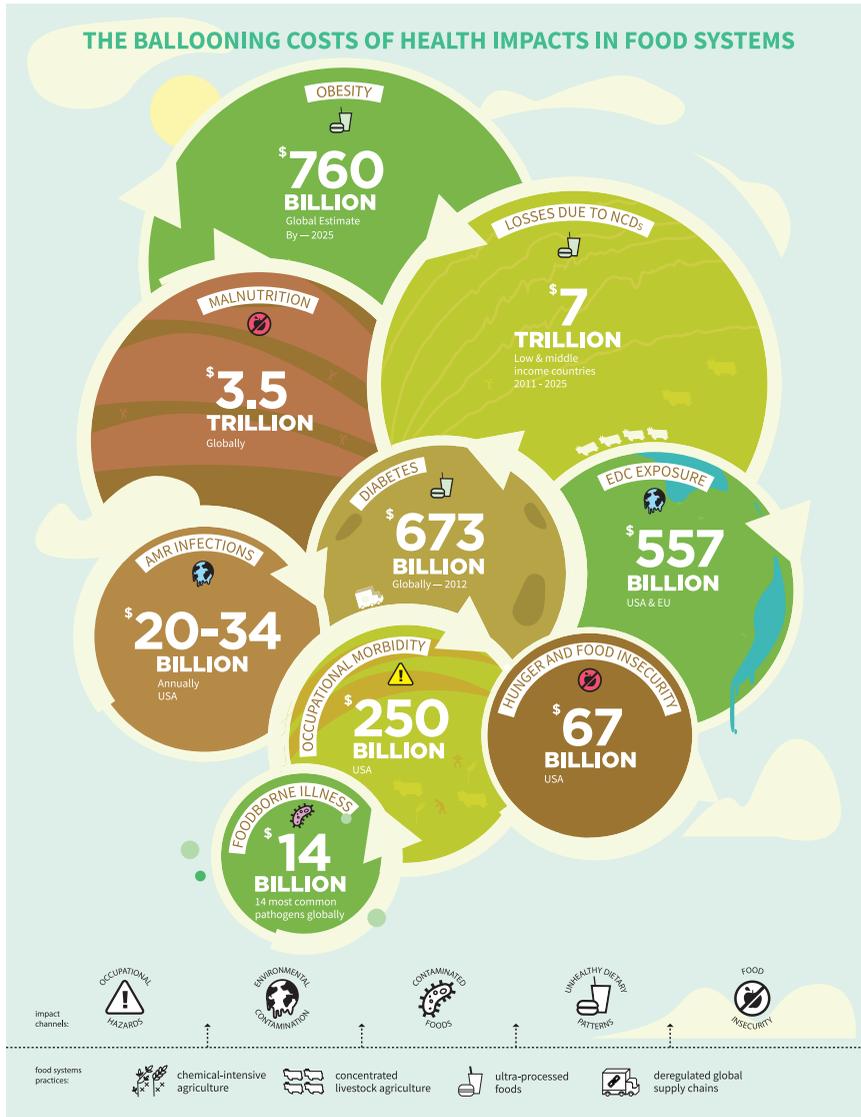


Fig. 1. The ballooning costs of health impacts Health impacts in food systems generate major economic costs in addition to the severe human costs. This illustration brings together some recent annual estimates of the most costly impacts associated with food systems.

increasingly be informed by a diversity of actors, sources of knowledge and disciplines, and by the collective strength, consistency, plausibility, and coherence of the evidence base.

Five co-dependent leverage points can be identified for building healthier food systems. These leverage points indicate the way towards changes that, collectively, can provide a new basis of understanding and action to build healthier food systems.

Leverage point 1: PROMOTING FOOD SYSTEMS THINKING. Food systems thinking must be promoted at all levels, i.e., we must systematically bring to light the multiple connections between different health impacts, between human health and ecosystem health, between food, health, poverty, and climate change, and between social and environmental sustainability. Only when health risks are viewed in their entirety, across the food system and on a global scale, can we adequately assess the priorities, risks, and trade-offs underpinning our food systems, e.g., the provision of low-cost food versus systematic food insecurity, poverty conditions, and environmental fallout of the industrial model. All of this has profound implications for the way that knowledge is developed and deployed in our societies, requiring a shift toward interdisciplinarity and transdisciplinarity in a range of contexts (e.g., new ways of assessing risks; changes in the way that university and school curricula are structured). Concepts such as “sustainable diets” and “planetary health” help to promote holistic scientific discussions and to pave the way for

integrated policy approaches. Food systems thinking can also be encouraged on a smaller scale through initiatives that reconnect people with the food they eat (e.g., community supported agriculture, school vegetable gardens).

Leverage Point 2: REASSERTING SCIENTIFIC INTEGRITY AND RESEARCH AS A PUBLIC GOOD. Research priorities, structures, and capacities need to be fundamentally realigned with principles of public interest and public good, and the nature of the challenges we face (i.e., cross-cutting sustainability challenges and systemic risks). Specific measures are needed to counter the influence of vested interests in shaping scientific knowledge on the health impacts of food systems, and to reduce the reliance of researchers on private funding (e.g., new rules around conflicts of interest in scientific journals, initiatives to fund and mandate independent scientific research and independent journalism on the health impacts of food systems). Different forms of research involving a wider range of actors and sources of knowledge are also required to rebalance the playing field and challenge prevailing problem framings (e.g., industry-leaning approaches; a “Global North” bias; approaches that exclude impacts on certain populations). Further investment in large-scale data gathering by intergovernmental organizations may also be required.

Leverage Point 3: BRINGING THE ALTERNATIVES TO LIGHT. We need to know more about the positive health impacts and positive externalities of alternative food and farming systems (e.g., agroecological crop and livestock management approaches that build soil nutrients, sequester carbon in the soil, or restore ecosystem functions such as pollination and water purification). It is crucial to document and communicate the potential of alternative systems to: reconcile productivity gains, environmental resilience, social equity, and health benefits; strengthen yields on the basis of rehabilitating ecosystems (not at their expense); build nutrition on the basis of access to diverse foods; and, redistribute power and reduce inequalities in the process. These outcomes must be seen as a package and as a new basis for delivering health — one in which healthy people and a healthy planet are co-dependent. A complete picture of the alternatives also requires more documentation of real-life experimentation at the policy level. A solid information base on alternative food systems — how they perform, and how they can be effectively promoted through policy — can challenge the assumption that an ever-more industrial logic is the only solution for addressing health impacts in food systems.

Leverage Point 4: ADOPTING THE PRECAUTIONARY PRINCIPLE. The negative health impacts identified in the report are interconnected, self-reinforcing, and systemic in nature. However, this complexity cannot be an excuse for inaction. Disease prevention must increasingly be understood in terms of identifying specific risk factors (not the cause) by the accumulation of evidence from many different studies, from many different disciplines, as well as in terms of the collective strength, consistency, plausibility, and coherence of the evidence base. In this light, there is a clear need to call upon the precautionary principle — developed to manage these complexities and requiring policymakers to weigh the collective evidence on risk factors and act accordingly — to protect public health.

Leverage Point 5: BUILDING INTEGRATED FOOD POLICIES UNDER PARTICIPATORY GOVERNANCE. Policy processes must be up to the task of managing the complexity of food systems and the systemic health risks they generate. Integrated food policies and food strategies are required to overcome the traditional biases in sectoral policies (e.g., export orientation in agricultural policy) and to align various policies with the objective of delivering environmentally, socially, and economically sustainable food systems. Integrated food policies allow trade-offs to be weighed up, while providing a forum for long-term systemic objectives to be set (e.g., reducing the chemical load in food and farming systems; devising strategies for tackling emerging risks such as antimicrobial resistance). These processes must be participatory. The general public must become a partner in public risk management and priority-setting, and buy into the rationale and priorities underpinning it.

The monumental task of building healthier food systems requires more democratic and more integrated ways of managing risk and governing food systems. A range of actors — policymakers, big and small private sector firms, healthcare providers, environmental groups, consumers’ and health advocates, farmers, agri-food workers, and citizens — must collaborate and take shared ownership in this endeavour.



SECTION 1

INTRODUCTION: UNDERSTANDING HEALTH IMPACTS IN A FOOD SYSTEMS CONTEXT

The food systems that we inherit in the 21st century represent major achievements of human civilization. Contrasted with millennia of subsistence diets for most of the population, today's food systems have succeeded in delivering abundant food in many parts of the world. Paradoxically, they also represent some of the greatest threats to our continued health and prosperity.

The environmental and socio-economic fallout of our food systems is of major concern. Today, food systems are estimated to contribute up to 30% of greenhouse gas (GHG) emissions (Niles et al., 2017). Meanwhile, 70% of all water withdrawn from aquifers, streams, and lakes is used for agriculture, often at unsustainable rates (FAO, 2011). The agricultural sector is responsible for nitrate, phosphorus, pesticide, soil sediment, and pathogen pollution in soil and water (Parris, 2011). Furthermore, agricultural systems have contributed significantly to land degradation as well as to the destruction of natural habitats and losses of wild biodiversity around the world (Scherr and McNeely, 2012).

Food systems are also failing food producers themselves. Many small farmers struggle to emerge above subsistence level, often lacking access to credit, external inputs, technical support, and markets or facing the uncertainties of volatile prices (FAO, 2004; Graeub et al., 2016). Farms in the Global North may be bigger and more capitalized, but they too face high risks and uncertainties, and farming incomes show little prospect of rising sustainably and

remain highly reliant on government subsidies (European Commission, 2014). While food and agriculture generate increasing value for input providers, food commodity traders, and global retail giants, decent livelihoods remain out of reach for many of those employed in food systems.

The negative impacts of food systems on human health is an area of growing attention and growing concern. The health impacts associated with food systems are highly diverse in terms of where they originate, what types of health conditions they are associated with, and who is affected. These pathways are multiple and interconnected. However, the full picture is often lost from view, allowing the connections to be obscured and the root causes of poor health to be left unaddressed. Too often the negative health impacts are disconnected from one another, from the food systems practices that systematically generate health risks, and from the underlying environmental and socio-economic conditions for health — conditions that are undermined by food systems activities. They are discussed in different bodies of literature and different fora, and they are addressed — if at all — by different types of policies. For example, discussion around obesity is commonly linked to questions of lifestyle and physical exercise, but is not systematically connected to the food and farming systems that play a key role in determining diets. And while agriculture is the leading contributor to air pollution in several regions of the world, the question is rarely addressed with regard to food production practices or in dialogue with food and farming actors. The breadth and complexity of food systems makes it highly challenging to capture the whole range of health impacts, and to draw meaningful conclusions on the picture that emerges.

The negative impacts of food systems on human health is an area of growing attention and growing concern.

This report seeks to provide a comprehensive overview, identifying 1) the multiple, interconnected ways in which food systems affect human health, and 2) how the prevailing power relations and imperatives in food systems help to shape our understanding of the impacts they generate. In other words, the report asks why evidence gaps persist, why impacts are systematically reproduced, and why certain problems are not politically prioritized (i.e., the political economy of health impacts in food systems). In doing so, it brings the food–health nexus into focus, i.e., the web of interactions, imperatives, and understandings at the intersection of food and health.

The report is structured around the following questions:

- **How do food systems affect human health? How much do we know?** (Section 2)
- **What holds back our understanding of these impacts and our ability to address them?** (Section 3)
- **How can we build a stronger basis for acting on health risks in food systems?** (Section 4)

The analytical lens we use to address these questions reflects the following perspectives:

A food systems approach

Bringing various health impacts together in one analysis is based on the premise that food systems provide a meaningful lens for understanding and addressing these impacts. Food systems refer not only to market transactions and connections between different points in the food chain (e.g., agriculture and food retail), but also to a broader web of institutional and regulatory frameworks, as well as the prevailing conditions in which science and knowledge are generated. This approach understands that the various components of food systems (e.g., trade policies, agricultural subsidies, market structures and prices, research and educational priorities) have co-evolved over time to become mutually reinforcing, with powerful coalitions of interest evolving alongside them (IPES-Food, 2015).¹ This analysis therefore considers that different problems in food systems are deeply interconnected, mutually reinforcing, and subject to systemic dynamics. Considering various health impacts collectively is not intended to downplay their specificities or the need for specific actions to address them. Rather, a food systems approach emphasizes the connections between them, and the potential of joined-up solutions to break the current cycles and co-dependencies. The food systems thinking embodied in this analysis is both a means and an end: it is a way of bringing the breadth of health impacts and connections between them to light, and, if applied to scientific inquiry and policymaking, could pave the way for health impacts to be comprehensively addressed.

A political economy approach

As will be described in Section 2, the various health impacts in food systems are widespread, severe, and increasingly costly in human and economic terms. Moreover, many of these impacts are well known to the public (e.g., people are confronted with a plethora of information about the nutritional benefits or risks associated with specific foods), suggesting that an urgent case for reforming food and farming systems can be made on the grounds of protecting human health. This report is premised on the view that actions to address these impacts have been incommensurate to the challenge, and that health is an under-exploited leverage point for food systems reform. This calls attention to the political economy of food systems, i.e., how and by whom priorities are set and decisions are made. In other words, we must ask how our knowledge of these impacts is shaped, why evidence gaps persist, why impacts are systematically reproduced, and why certain problems are not politically prioritized — even as they are increasingly documented. Power — to achieve visibility, to shape knowledge, to frame narratives, and to influence policy — is at the heart of the food–health nexus, and will therefore be central to this analysis. Power imbalances between different regions of the world and between different groups in society are taken into account throughout.

The report asks why evidence gaps persist, why impacts are systematically reproduced, and why certain problems are not politically prioritized. In doing so, it brings the food–health nexus into focus, i.e., the web of interactions, imperatives, and understandings at the intersection of food and health.

A public health perspective

A public health perspective on the analysis of food systems focuses on primary disease prevention, management of chronic conditions, and the general promotion of health (Neff and Lawrence, 2014). This report aims not simply to study how current food systems impinge on health (the symptoms), but to go beyond in order to identify the root causes of harm and how these could be addressed. It therefore emphasizes the need to explore the social, structural, and environmental determinants of health associated with food systems, and to identify interventions that can potentially benefit many people at a time, ensuring and enhancing conditions for population health.

A critical approach to “evidence” and consideration of diverse sources of knowledge

Given the focus on how knowledge and understandings are shaped, the evidence that informs this analysis must be treated critically. In light of the self-reinforcing power relations described above, it is crucial to open the door to different sources of knowledge, and to cast the net wide in terms of what is on the table (i.e., what might be considered a health impact of food systems). This report therefore draws on a wide range of evidence from peer-reviewed academic journals, civil society reports, media coverage, and a range of other sources in describing the health impacts associated with food systems. It also draws on studies from a variety of fields and disciplines, in line with the diverse nature of health risks in food systems. Moreover, it considers the impacts on a global scale, and refers to data and evidence from a variety of geographical settings (challenges on this front are addressed in Section 3). While this report does not represent a comprehensive “meta-review,” it is hoped that the evidence gathered in Section 2 can be used alongside other reviews of a similar nature to update the state of play on the health impacts of food systems, what we know about them, and how they might be addressed. Looking at these diverse impacts side by side allows us to identify common drivers in specific food system practices. However, the primary focus is on understandings and knowledge more broadly. The evidence review paves the way for key patterns and mechanisms to be observed in the way evidence is generated, interpreted, framed, communicated, and translated into policy action. In Section 3, the report identifies the influence of specific actors, specific narratives, and specific worldviews in framing the problems and diagnosing the solutions. The evidence base is therefore considered as a dynamic whole with many moving pieces, underpinned by various assumptions and competing interpretations of what constitutes a robust methodology and a sufficient basis for action. The focus throughout remains on the science-policy interface (or science-policy-public interface): where information is transmitted, where understandings are shaped and reshaped, where the diverse strands of evidence accumulate, and where that evidence must ultimately be parsed and translated into action. Precautionary approaches focused on taking action in a context of complexity and uncertainty will be an important reference point in the discussion (see Section 4).

This report therefore emphasizes the need to explore the social, structural, and environmental determinants of health associated with food systems, and to identify interventions that can potentially benefit many people at a time, ensuring and enhancing conditions for population health.

Five key channels of impact

In this report, the initial discussion of health impacts in food systems in Section 2 is grouped into five “channels of impact,” representing distinct types of impact and distinct risk transmission pathways. The five channels are:



IMPACT CHANNEL 1 OCCUPATIONAL HAZARDS

Physical and mental health impacts suffered by farmers, agricultural labourers, and other food chain workers as a result of exposure to health risks in the field/factory/place of work.

People get sick because they work under unhealthy conditions.



IMPACT CHANNEL 2 ENVIRONMENTAL CONTAMINATION

Health impacts arising via the exposure of whole populations to contaminated environments “downstream” of food production, through pollution of soil, air, and water resources or exposure to livestock-based pathogens.

People get sick because of contaminants in the water, soil, or air.



IMPACT CHANNEL 3 CONTAMINATED, UNSAFE, AND ALTERED FOODS

Illnesses arising from the ingestion of foods containing various pathogens (i.e., foodborne disease) and risks arising from compositionally altered and novel foods.

People get sick because specific foods they eat are unsafe for consumption.



IMPACT CHANNEL 4 UNHEALTHY DIETARY PATTERNS

Impacts occurring through consumption of specific foods or groups of foods with problematic health profiles. These impacts affect people directly through their dietary habits, as shaped by the food environment.

People get sick because they have unhealthy diets.



IMPACT CHANNEL 5 FOOD INSECURITY

Impacts occurring through insufficient or precarious access to food that is culturally acceptable and nutritious.

People get sick because they can't access adequate, acceptable food at all times.

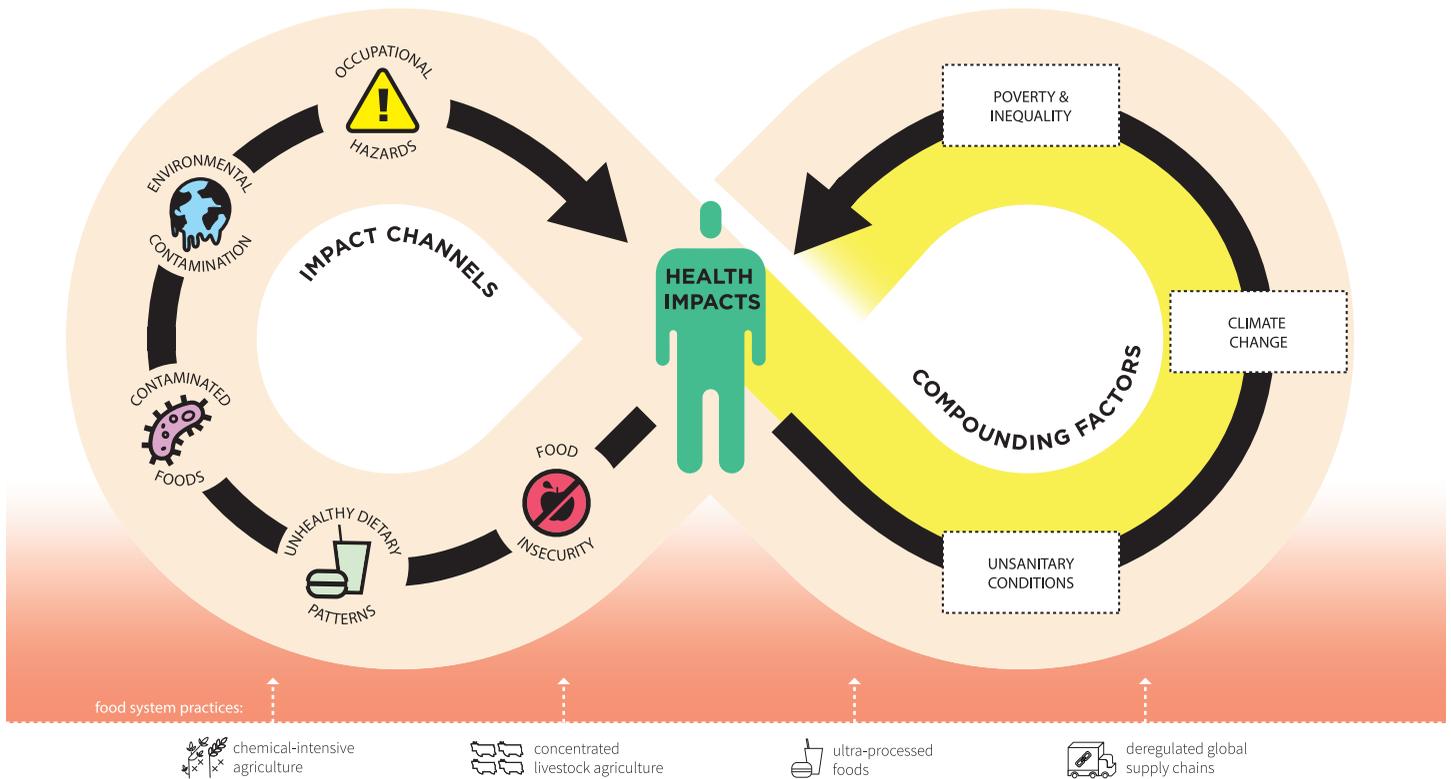


Fig. 2. How food systems affect human health: Five channels of impact

Food systems affect human health through five key channels. The resulting health impacts are exacerbated by a series of factors shown on the right of the diagram; these “compounding factors” will be described in Section 3.

Given their complexity, it is impossible, at any one time, to fully describe global food systems to identify all the pathways that have consequences for health — not least because many of the pathways are indirect, with factors outside food systems also playing an important role (see Section 3). The five impact channels are intended to provide a basic framework for organizing the various impacts potentially arising from food systems, and are therefore framed very broadly. Where we set the boundaries of food systems impacts, and which stakeholders and sources of knowledge are taken into consideration, have major implications for the picture that emerges.

The choice of the five channels and the specific impacts described within them reflect the following considerations:

1. The five channels, and the ensuing analysis, are structured around negative health impacts. However, positive health impacts (e.g., specific practices or specific dietary patterns that promote health) are a key piece of the evidence base and a key factor in building our understanding of how health impacts occur. The case for comprehensively documenting positive impacts and externalities is made in Section 4.
2. The impact channels are designed to focus on the different ways in which people get sick, rather than grouping impacts according to who

is affected or where they occur in the agri-food value chain. Neither the health conditions that arise, nor those suffering from them, are mutually exclusive between the channels. Health conditions such as cancers, obesity, and depression appear in multiple channels, and a person might be exposed to health risks through multiple channels. Moreover, many of these impacts cannot be located at a single point in the chain, or classified as “supply-side” or “demand-side” problems. For example, unhealthy dietary patterns are mediated by production choices affecting the nutrient value of foods, the relative prices of different foods, access to different foods by different population groups, as well as people’s personal choices and the myriad factors shaping those choices (e.g., marketing, general knowledge of foods and diets).

3. The examples of specific impacts (e.g., nitrate contamination of drinking water as a form of environmental contamination) are not exhaustive, and were selected on the basis of a very substantial literature review, with a view to covering health impacts that appear *a priori* to: i) have the most severe impacts on individuals; ii) have an impact on the greatest number of people; and, iii) have the strongest associations with food systems. The objective, however, is not to rank these impacts in terms of their relative significance; rather, it is to allow the bigger picture to emerge in terms of our knowledge, understanding, and ability to act on the various health impacts of food systems. Indeed, by looking at the bigger picture, it is possible to revisit key assumptions through the analysis, and to reflect critically on why some problems appear *a priori* to be more pressing than others.

Impacts associated with industrial food and farming systems are prominent in the analysis. A series of narratives and imperatives have co-evolved alongside the industrial model, and play a key role in framing debates around all aspects of food systems, including health risks and how to address them.

Impacts associated with “industrial” food and farming systems are prominent in the analysis, reflecting the goal of capturing the impacts of most relevance now and in the future. This refers to systems that are analogous to industrial processes in their scale and task segregation, and seek to derive productivity gains from specialization, intensification, and concentration of production and distribution (IPES-Food, 2016). While manifesting itself in different ways and to different extents, an industrial logic now underpins agricultural development in many countries around the world, either coexisting with or having almost entirely replaced non-industrial systems. Moreover, a series of narratives and imperatives have co-evolved alongside the industrial model, and play a key role in framing debates around all aspects of food systems, including health risks and how to address them (see Section 3). However, the industrial model is not the only source of health risks in food systems, and nor are understandings about food–health linkages influenced only by industrial logics and their proponents. Indeed, the tension between different food and farming models — and the premising of solutions on further industrialization — is brought to light throughout the discussion.



SECTION 2

**HOW HEALTH IMPACTS OCCUR IN FOOD SYSTEMS
AND HOW MUCH WE KNOW ABOUT THEM**
FIVE KEY CHANNELS OF IMPACT





IMPACT CHANNEL 1 OCCUPATIONAL HAZARDS



Worldwide, the agricultural sector is one of the most hazardous to human health. The risk of occupational injury and death is much higher in agriculture, fishing, and forestry than in any other sector, with food manufacturing also presenting high rates of injuries and fatalities.

HOW DO HEALTH IMPACTS OCCUR THROUGH THIS CHANNEL?

Worldwide, the agricultural sector is one of the most hazardous to human health (Cole, 2006; FCWA, 2012; ILO, 2009). The risk of occupational injury and death is much higher in agriculture, fishing, and forestry than in any other sector (NIOSH, 2012), with food manufacturing also presenting high rates of injuries and fatalities (Neff, 2014). Some of the most important occupational hazards arising in food systems — and the health conditions with which they have been associated — are described below.

Acute pesticide poisoning²

Acute pesticide poisoning on farms remains a major health threat, particularly in countries where health and safety regulations are weaker and/or not fully implemented (Cole, 2006; Eddleston et al., 2002; Gunnell et al., 2007). Pesticides are responsible for an estimated 200,000 acute poisoning deaths each year, 99% of which occur in developing countries (Elver, 2017). Acute pesticide poisoning can occur due to accidents in the workplace or the home, for instance due to splashes or spills when mixing or applying substances. Many of these incidents tend to occur because protective clothing is unavailable, damaged, too expensive, or too cumbersome and uncomfortable in hot climates (Eddleston et al., 2002). Inappropriate handling and disposal of pesticide containers and their storage at home are additional risk factors (Konradsen et al., 2003). Symptoms of pesticide poisoning include fatigue, skin rashes and discomfort, weakness, circulatory problems, head- and body aches, and in severe cases, coma and death (PAN Germany, 2012).

ESTIMATED ANNUAL FATAL INJURY RATE IN THE AGRICULTURAL SECTOR



Low-dose chemical exposure

Lower-dose, chronic exposure to many pesticides, and particularly Endocrine Disrupting Chemicals (EDCs), has been clearly linked to a number of long-term health effects that may occur even when individuals use the recommended safety procedures when handling pesticides and chemicals (Elver, 2017). Both hematopoietic cancers (those of the blood, bone marrow, and lymph nodes) (Merhi et al., 2007) and solid tumours (in the brain, colon, prostate, or kidney) have been linked to pesticides in large-population studies (Bassil et al., 2007; Blainey et al., 2008).³ Several studies have also linked occupational exposure to pesticides with prostate cancer (Alavanja et al., 2003; Dich and Wiklund, 1998; Mills and Shah, 2014; Mink et al., 2008; Settini et al., 2003; Sharma-Wagner et al., 2000). The risks of long-term exposure — particularly to EDCs — extend beyond the farm; chronic chemical exposures will be addressed more broadly under Impact Channel 2 (Environmental Contamination).

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Exposure to airborne substances

Another occupational hazard on farms arises from exposure to a range of airborne substances and compounds, including pesticides, dust, fertilizers, plant growth regulators, crops and related allergens, pollen, animal waste, and other micro-organisms (Frank et al., 2004; Schenker, 2011). Exposure to these substances has been found to contribute to various respiratory diseases in farmworkers in a range of countries, e.g., the United States (Das et al., 2001), the United Arab Emirates (Beshwari et al., 1999), Ethiopia (Mekonnen and Agonafir, 2002), the Philippines (Lu, 2005), and New Zealand (Fishwick et al., 1997).

Exposure to zoonotic disease and antimicrobial resistance

Farmers and farmworkers handling livestock face major exposure risks in regard to zoonotic diseases and the spread of antimicrobial-resistant bacteria; these risks (which also affect wider populations) will be addressed in Impact Channel 2 (Environmental Contamination).

Injury risks on farms and fishing vessels

Studies in developed countries have shown that farm operators and family members are at high risk of injury due to the equipment they use and the animals they handle on a daily basis.⁴ The most common injuries include musculoskeletal conditions (sprains, strains, broken bones), crushes (from machinery and animal handling), hearing loss (from operating large machines and small engines), and head injuries (from tractor rollovers and falls). Fatalities have been found to occur most often in vehicle or machinery-related incidents (Lovelock et al., 2008). High rates of injury (fatal and nonfatal) resulting from machinery or animal handling are also reported for concentrated animal feeding operations (CAFOs) (Mitloehner and Calvo, 2008). Farm labourers, and particularly migrant workers, tend to face additional injury risks as a result of work conditions that require the same position to be maintained over extended periods of time, heavy lifting and carrying, working with heavy machinery or on ladders (Anthony et al., 2008; Arcury and Quandt, 2007; Hansen and Donohoe, 2003), and long working hours in hot conditions (potentially leading to dehydration, heat exhaustion, and heat strokes) (Cole, 2006; Villarejo, 2012). Fishers also face a specific and significant set of risks due to: heavy, dangerous equipment; tasks requiring repetitive motions; slippery surfaces; the risk of fishing vessels sinking; and, the remoteness of small fishing vessels from shore, with limited access to emergency medical assistance (Windle et al., 2008).

Injury risks in food processing, distribution, and retail

Food production lines generate high risks of injury, particularly in the high-pressure work environments of industrialized meat packing and poultry processing plants, where work proceeds at a fast pace over long shifts (Campbell, 1998; Grzywacz et al., 2007; Lloyd and James, 2008). Common injuries include cuts and lacerations from using sharp equipment, and acute and repetitive strain musculoskeletal injuries (e.g., cumulative trauma disorders and chronic back pain). Processing workers operating in low temperatures (e.g., in refrigeration rooms) face a series of heightened health risks (FCWA, 2012; Kaminski et al., 1997; Sormunen et al., 2009; Lloyd and James, 2008).⁵ Further injury risks accrue through food distribution, transport, and retail. Warehouse workers also suffer from back injuries, slips and falls, and motor vehicle-related injuries (Harrington, 2006). The supermarket and restaurant industries have above average injury rates due to falls, back injuries, musculoskeletal disorders, cuts, lacerations, and burns (Alamgir et al., 2007; Baron and Habes, 1992; Gleeson, 2001).

Stressful working conditions (mental health impacts)

In addition to physical health risks, farming has been identified as one of the ten most stressful professions in the world (Lunner Kolstrup et al., 2013). The inherent uncertainties of agriculture (e.g., weather patterns, input and output prices) can create a feeling of powerlessness for farmers, in some cases lowering their self-esteem and increasing the likelihood of depression (Fetsch, 2014). The mental strain of adapting to and managing complex farm

ANNUAL DEATHS
RESULTING FROM
AGRICULTURE



170,000
DEATHS

ANNUAL DEATHS
RESULTING FROM
FISHERIES



24,000
DEATHS

environments can lead to exhaustion, concentration problems, insomnia, psychosomatic disorders, family issues, and alcohol and drug abuse (Brumby et al., 2013; London, 2000). Furthermore, the constant financial pressure, low control, and minimal social support experienced by farmers can cause anxiety, depression, and mental illness, and can even contribute to suicide (Dongre and Deshmukh, 2012; Lunner Kolstrup et al., 2013).⁶ A meta-analysis of 34 studies found that agricultural workers were 1.6 times more likely to commit suicide than the general population (Milner et al., 2013). The liberalization of agricultural markets, the abolition of price supports in some countries, the exposure to volatile international commodity markets, and increased debt loads in increasingly capital-intensive production systems have also contributed to the mounting pressures faced by farmers, with serious impacts on their mental health (Fraser et al., 2005; Lunner Kolstrup et al., 2013). In particular, the rise of contract farming has been associated with increased stress as a result of farmers losing control over inputs and management, having to implement decisions they might not agree with, e.g., costly infrastructure upgrades with implications for indebtedness, and increasing dependency on parent companies — sometimes leading to a climate of intimidation (Jenner, 2014; Murphy, 2010; Pew Charitable Trusts, 2013). Stress, and the associated health impacts, is also a major problem beyond agriculture. High productivity demands, low wages and job security, harassment, and risks of sexual assault afflict the general health and well-being of workers throughout food systems (FCWA, 2012; SPLC, 2010). In particular, industrial food processing and factory settings have been identified as highly stressful environments due to the pace of the production line, few work breaks, and other factors such as chronic ambient noise (Grzywacz et al., 2007; Lunner Kolstrup et al., 2013). The psychological strain of working in these settings has in some cases been associated with high blood pressure and cardiovascular diseases (Ledésert et al., 1994).

In addition to physical health risks, farming has been identified as one of the ten most stressful professions in the world.

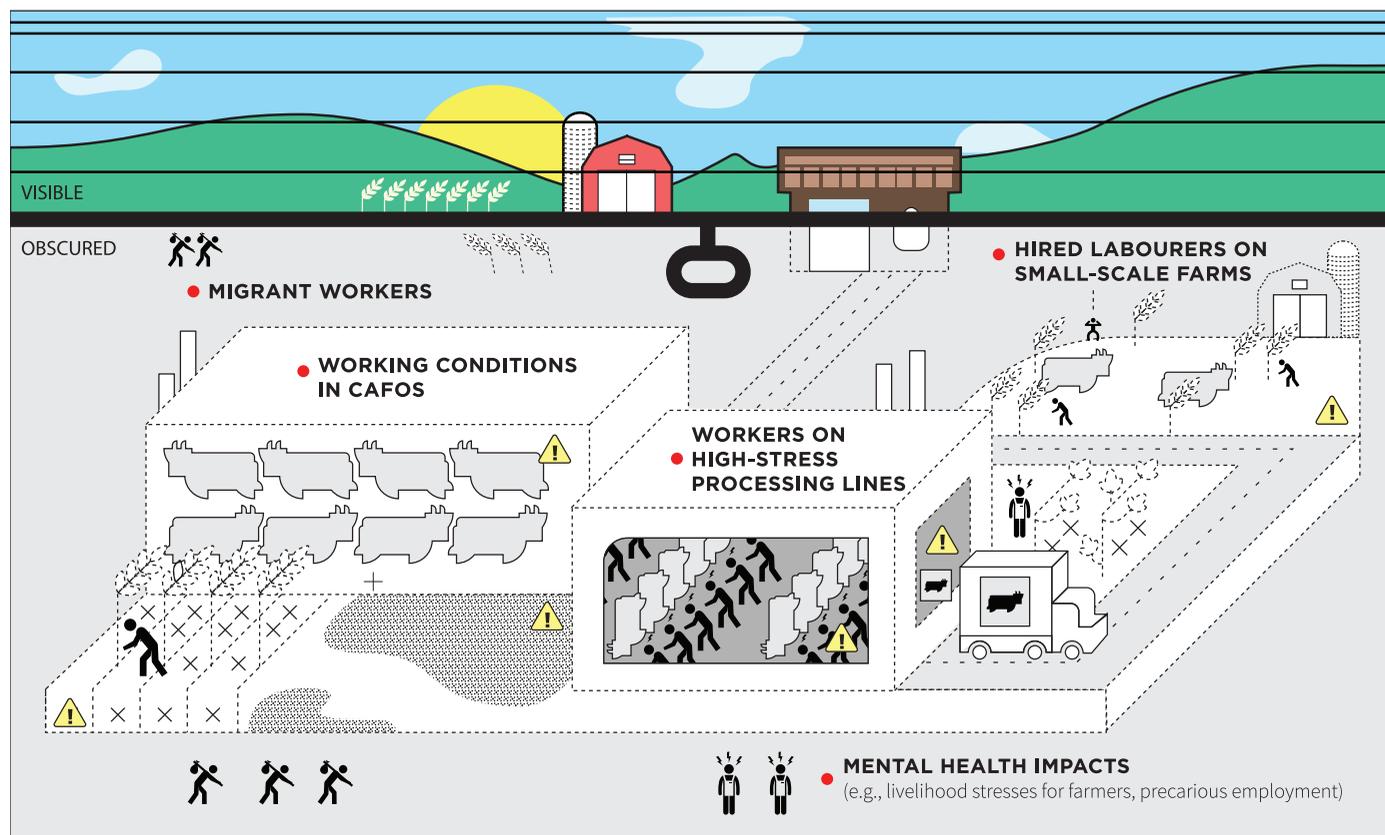
Who is affected?

While many occupational health impacts are of concern to food and farmworkers around the world, some tend to be more prevalent in developing countries, and are generally preventable, i.e., contingent on effective regulation and the application of safety norms. For instance, although developing countries accounted for only 20% of all pesticide use in the early 1990s, they saw more than 99% of poisonings, because more toxic products were used under less regulated conditions (Cole, 2006). The prevalence of migrant labour in agricultural work in many countries — and the resulting cultural and language barriers — tends to exacerbate these risks, through, for example, misunderstandings of safety precautions, misinterpretation of pictograms, or unsafe use of hazardous tools due to inadequate training and supervision (Cole, 2006; PAN Germany, 2012). In both developed and developing countries, many of the occupational hazards relate to more systemic conditions of industrial production processes, such as the existence of repetitive tasks, the use of heavy and dangerous equipment, and the mental strain of high-pressure work with low control and high uncertainty.

Box 1

COUNTING THE HUMAN AND ECONOMIC COSTS OF OCCUPATIONAL HAZARDS IN FOOD SYSTEMS: SELECT ESTIMATES

- Agriculture continues to be the sector of the economy with the **highest occupational risk**, even in highly developed nations (Nelson et al., 2012).
 - Globally, production agriculture is estimated to cost **170,000 lives per year** and commercial fishing **24,000 per year** (Nelson et al., 2012, p. 347).
 - The estimated **annual fatal injury rate** in the agricultural sector ranges between **7.8/100,000 workers** in high-income countries, **18.9/100,000 workers in Africa**, and **24/100,000 workers in East and Southeast Asia** (Nenonen et al., 2014).
 - The fatal incidence rates in a cross-section of European and North American **fisheries** are about **25 to 50 times higher than for onshore workers**, at an average of **100/100,000** full-time equivalent workers (Jensen et al., 2014).
 - Although developing countries accounted for only **20% of all pesticide use** in the early 1990s, they accounted for more than **99% of poisonings**, because more toxic products were used under more rudimentary conditions (Cole, 2006).
 - It is estimated that unintentional acute poisonings from chemicals (methanol, diethylene glycol, kerosene, pesticides, etc.) account for **346,000 deaths** and the loss of **7,445,000 Disability-Adjusted Life Years** annually, 71% of which would be preventable through improved chemical safety (Prüss-Ustün et al., 2011).
 - In the United States, almost **500 deaths** in 2010 were linked to production agriculture (476 farmers and farmworkers, as well as 60 commercial fishing deaths) (Nelson et al., 2012).
 - In a 17-state sample from the United States in 2012, the farming, fishing, and forestry industries had a suicide rate of **84.5/100,000 people** (90.5 among males), almost **five times as high** as the rate of the general population (McIntosh et al., 2016).
 - In **India**, it is estimated that in 2001, the farmer suicide rate was **12.9/100,000 people**, compared to the general population rate of 10.6 (Das, 2011).
 - Data from Australia and the United Kingdom showed **farmers' suicide rates twice as high** as the general population (ABC Australia, 2008; Gregoire, 2002).
 - Estimations of economic costs are difficult to come by, but in the United States, where direct and indirect costs from occupational morbidity and mortality amount to **US\$250 billion**, the **highest mortality rates** have been found to be in the agricultural, food manufacturing, and food preparation industries (Newman et al., 2015).
 - In Madhya Pradesh, India, in 2000, the cost of fatal and nonfatal injuries in agriculture was estimated at **US\$27 million** (Cole, 2006).
 - The human health costs of **pesticides** amounted to **\$787 million per year in the United States** in the early 1990s (Pimentel et al., 1992).
 - In the UK, it is estimated that the health-related benefits of withdrawing approval for seven active substances used in pesticides could reach £354 to £709 million of avoided healthcare costs for the maximum exposed farmworker population over 30 years. Extrapolating these figures, such benefits could reach **€3,568 to €7,160 billion over 30 years** for the entire **EU population** (Blainey et al., 2008).
-



HOW MUCH DO WE KNOW ABOUT THESE IMPACTS, AND HOW WELL ARE THESE FOOD-HEALTH LINKAGES UNDERSTOOD?

Occupational health hazards in food systems are well documented and understood. Still, several blind spots can be identified, both in terms of how and where negative impacts are accruing. For example:

- Under-reporting in informal and small-scale farming sectors**
 A large proportion of the agricultural labour force is engaged in the informal, unregulated sector — mostly in developing countries — where census data is poor (Kaewboonchoo et al., 2015). In some settings the total population of farmers is unknown, and there may therefore be widely varying accounts of the suicide and fatality rate as a percentage of the population. Smaller farms are often exempted from mandatory reporting of injuries; in the United States this effectively excludes an estimated 46% of direct-hire farm labourers from oversight (Villarejo, 2012), with similar issues likely to undermine reporting elsewhere.
- Under-reporting among insecure workforces**
 The insecure status of many food- and farmworkers means that occupational hazards are less likely to be reported, casting doubt on the

Fig. 3: Blind spots in the evidence base: under-reported and under-estimated occupational hazards in food systems

A range of occupational health impacts in food systems tend to be obscured from view, leaving major blind spots in the evidence base.

reliability of employer-reported occupational injury and illness data. Farmworkers may avoid drawing their employers' attention to injuries and illnesses for fear of termination, or lack of knowledge of their right to medical services. In turn, employers may have a financial incentive to under-report injuries and illnesses that occur on their premises in order to lower their workers' compensation insurance payments (Boden and Ozonoff, 2008; Rosenman et al., 2006; Villarejo, 2012). Furthermore, the biggest health risks tend to accrue to vulnerable groups — particularly hired and migrant labourers — making reporting even less likely. In the United States, hired farmworkers are estimated to face a risk of fatal occupational injury that is five times higher than the average worker in all civilian industries (Villarejo, 2012). Their precarious economic situation may force hired and migrant labourers to work longer hours, perform more strenuous or repetitive tasks, accept more dangerous jobs, and complain less about substandard working conditions (Ahonen et al., 2009). Studies in Australia, Greece, and Spain have shown that foreign workers have higher occupational injury rates than domestic workers, as a result of harsher working conditions, language, and communication barriers and lack of safety instructions (Ahonen et al., 2009; Alexe et al., 2003; Corvalan et al., 1994). Cultural and legal barriers may also prevent migrant workers from seeking out medical attention — leading to more protracted injuries (Otero and Preibisch, 2010). Outgrowers or contract farmers represent another key group whose exposure to illness and injury — particularly stress-related conditions — is likely to be underestimated, due to fear of speaking out against the parent companies on whom they are highly dependent (Jenner, 2014; Murphy, 2010). Illness and injury among fishers may also be under-reported due to unwillingness to take time off and forgo earnings; the most common fishing-related injuries are incurred by third mates, mates, and deck hands (Matheson et al., 2001), suggesting that once again those to whom the risks accrue may not be well-positioned to report and seek redress for the health impacts they suffer.

The biggest health risks tend to accrue to vulnerable groups — particularly hired and migrant labourers — making reporting of these impacts less likely.

- **Concentrated Animal Feeding Operations (CAFOs):**

- **Poor access to information**

- Another blind spot in terms of occupational hazards (and health impacts more broadly) concerns CAFOs, which typify livestock production in North America and increasingly in other parts of the world. Some studies have identified increased risks of injury as a result of the core characteristics of CAFOs, e.g., the high density of animals (Mitloehner and Calvo, 2008). Furthermore, risks to these workers have been identified through exposure to zoonotic diseases and antimicrobial resistance from animals (see Impact Channel 2). To date, CAFOs and other large-scale industrialized farming settings have been studied more in terms of community health (i.e., the impact of

environmental contamination on local populations) than from a farm-worker point of view, making it difficult to assess the occupational risks relative to other types of holdings, e.g., family farms (Mitloehner and Calvo, 2008). Attempts to survey the general conditions of CAFOs (e.g., from an animal welfare perspective) have run up against major obstacles in terms of refusal to grant access or to provide information on the holdings in question (Pew Commission, 2007; Safran Foer, 2010).

- **Mental health reporting: A major blind spot**

When compared with evidence on physical injury, the mental health and welfare of farming communities and agricultural workers has been relatively under-reported, understudied, and rarely quantified. In a rural context, mental health support is often less accessible. In tight-knit communities, seeking assistance may have a higher social cost, which limits the survey population (Kutner, 2014). The occurrence of untreated mental health problems in rural families can only be assessed through interview-based studies that often have small sample sizes and may not be generalizable. These shortcomings leave the evidence base over-reliant on incidence of suicide, which is the severest but not the only manifestation of mental health problems, and for which data is itself patchy. Suicides may be under-reported due to mischaracterization of the cause of death (e.g., classification as accidents). Furthermore, retired farmers, spouses, and farm hands, not categorized as farmers, are unlikely to be included in official statistics (Kölves et al., 2012). Stress-related impacts may be particularly important — and particularly hard to capture — when they interconnect with physical risks (see Section 3).

It is clear, therefore, that occupational hazards may be underestimated on several fronts, and are yet to be fully understood in terms of their scope (e.g., mental health impacts) and their longer-term chronic effects (e.g., low-dose pesticide exposure). The underestimation of occupational health impacts in food systems is closely linked to the vulnerable situation of those suffering them. As will be addressed in Section 3, how food system impacts are framed and circumscribed has major implications in terms of how well they are understood.



IMPACT CHANNEL 2 ENVIRONMENTAL CONTAMINATION



Nitrate and phosphorus pollution arising from chemical fertilizer use and feedlot runoff has been identified as a major health risk in agricultural areas and beyond.

HOW DO HEALTH IMPACTS OCCUR THROUGH THIS CHANNEL?

Food systems have been associated with negative human health impacts through a variety of different forms of environmental contamination, most commonly transiting through water and air pollution. Some of the key pollutants/sources of pollution are described below.

Nitrate and phosphorous pollution via fertilizer runoff

Nitrate and phosphorus pollution arising from chemical fertilizer use and feedlot runoff has been identified as a major health risk in agricultural areas and beyond, particularly in OECD countries (Turrall, 2012). A variety of practices in the intensive livestock sector, particularly the liquification and spraying of untreated animal feces onto soils, have been closely linked to water contamination and the resulting health impacts. Runoff into the groundwater system, through rain and soil seepage, takes with it nitrogen, phosphorus, other chemicals, metals (such as copper, zinc, and arsenic) added to animal feed, as well as multiple disease-carrying pathogens, such as *E. coli* (Anderson and Sobsey, 2006; Dan-Hassan et al., 2012). A number of cohort studies in the United States, Canada, Australia, and Europe have found elevated nitrate levels in groundwater that feed into the public water system of rural communities, and shown a positive association of water consumption with adverse health effects (Dubrowsky et al., 2010; Mannassaram et al., 2006; Brender and Meyer, 2016; Brender et al. 2013; Iowa Environmental Council, 2016). The health outcomes associated most strongly with excess nitrate intake from drinking water are bladder cancer, thyroid cancer, and non-Hodgkin's lymphoma (Iowa Environmental Council, 2016; Nolan et al., 2002). Strong associations have also been found with

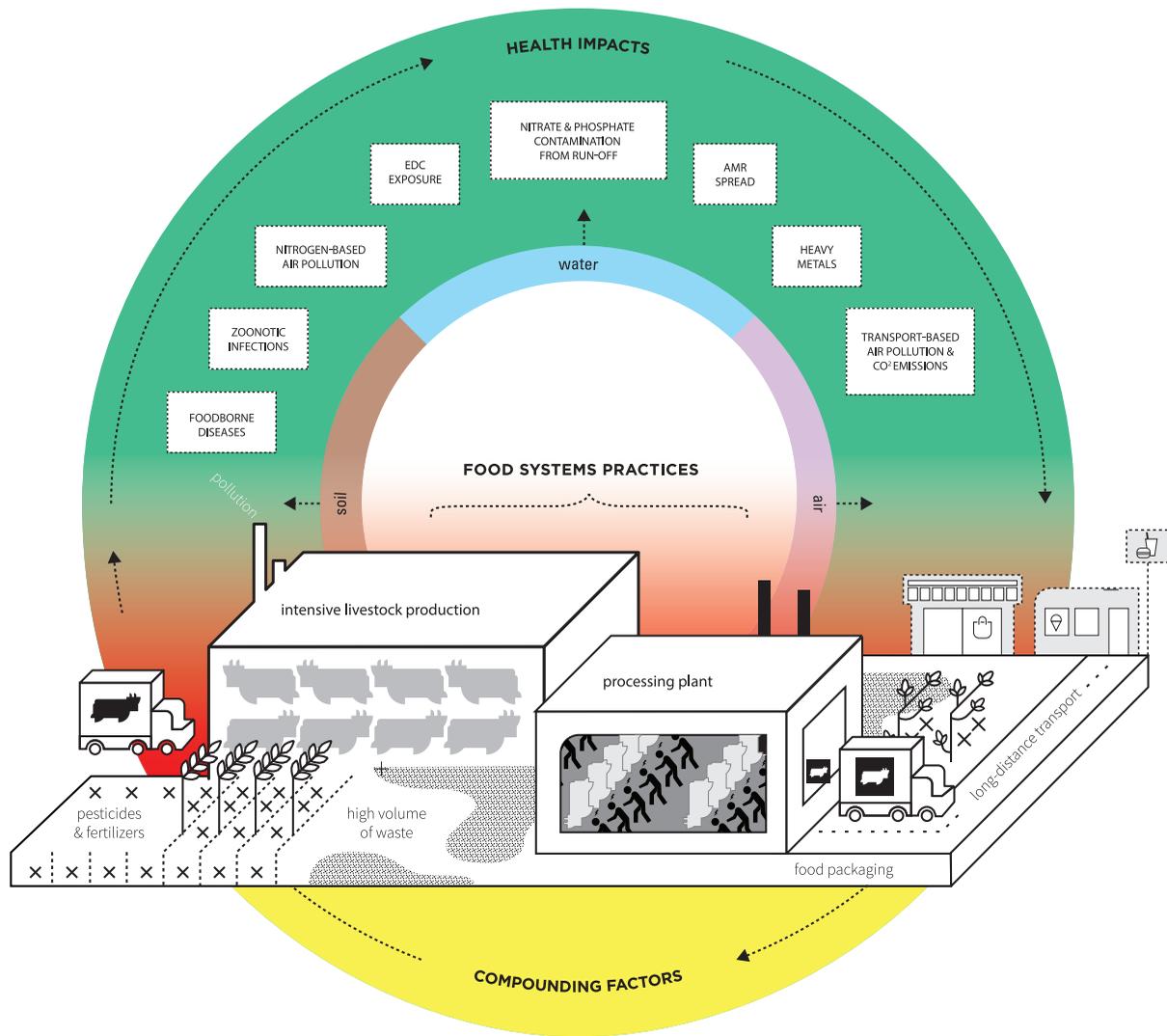


Fig. 4: Environmental contamination pathways

Environmental contamination risks arise from multiple food system activities, transit through multiple pathways (e.g., water, soil and air), and manifest themselves in a variety of severe health conditions.

structural birth defects (Gupta et al., 2008; Iowa Environmental Council, 2016), including congenital anomalies, neural tube defects and methemoglobinemia (blue-baby syndrome),⁷ as well as spontaneous abortions (Centers for Disease Control and Prevention, US, 1996). Less conclusive evidence also links high nitrate levels in potable water with colorectal cancer, ovarian cancer, thyroid dysfunction, and macular degeneration (Iowa Environmental Council, 2016).

Transmission of zoonotic diseases via livestock

The emergence of new zoonotic infectious diseases occurs most often where the natural habitat and populations of wild animals overlap with the anthropologically controlled habitats and populations of domesticated animals (Jones et al., 2013; Leibler et al., 2009; Patz et al., 2004). As food production encroaches onto formerly untouched ecosystems, often via deforestation, humans and domestic animals are exposed to wildlife and the diseases they carry (Goodwin et al., 2012; Morse, 2004; Patz et al., 2004). Domestic livestock that come into contact with wildlife can then serve as “amplifier hosts,” spreading

the contracted disease to their human handlers through close and frequent contact (Graham et al., 2008; Liverani et al., 2014; Morse, 2004). This creates opportunities for the emergence and spread of diseases through animal-to-animal, animal-to-human, and human-to-human transmission vectors, endangering farmworkers, their families, and surrounding communities (Graham et al., 2008; Jones et al., 2013; Slingenbergh et al., 2004). The conditions of intensive livestock production also help to generate and exacerbate zoonotic disease risks through a range of channels. In industrial feedlots or CAFOs, the high number and density of genetically uniform animals, and the concentration of waste, creates a favourable environment for pathogens to spread, adapt, and reproduce at a rapid pace (Liverani et al., 2014; Slingenbergh et al., 2004). Furthermore, livestock bred for specialized traits — particularly for short production cycles — tend to be raised in conditions that further amplify the risks of pathogen spread and adaptation. Animal feed containing contaminated animal tissues and by-products such as offal, bone and blood meal, and nervous system and brain tissue represents another avenue for inter-farm and inter-species disease transmission (e.g., BSE/Creutzfeldt-Jacob disease) (Gilchrist et al., 2007; Morse, 2004). Up to 14% of the enteric disease burden in the United States can be attributed to direct animal contact (Hale et al., 2012). The risks of zoonotic pathogen emergence and spread may be particularly high in emerging economies, where meat production is rapidly intensifying to meet growing demand and where livestock systems may be less regulated. In recent years, increasing attention has been paid to newly emerging epidemic zoonoses such as avian influenza (H5N1) and severe acute respiratory syndrome (SARS) (ILRI et al., 2012; Liverani et al., 2014; Morse, 2004).

In industrial feedlots or CAFOs, the high number and density of genetically uniform animals, and the concentration of waste, creates a favourable environment for pathogens to spread, adapt, and reproduce at a rapid pace.

Spread of antimicrobial resistance (AMR)

The spread of bacteria having developed resistance to the antimicrobials used increasingly on intensive livestock farms, i.e., antimicrobial resistance (AMR), is another major health concern transiting through the environment. In many regions of the world, antibiotics are regularly administered to animals in nontherapeutic ways, i.e., in constant low doses to prevent disease outbreaks and/or accelerate the growth process. More antibiotics are used worldwide for these purposes than to treat human diseases (Ahmed and Shimamoto, 2015; CDC, 2013; Laxminarayan et al., 2016; Spellberg et al., 2016; WHO, 2012). For example, in Canada and the United States, animals account for at least 80% of antibiotic use (Casey et al., 2013; Sibbald, 2012). Antibiotics are increasingly being used for similar purposes in intensive aquaculture systems (Meek et al., 2015). Many of the antibiotics used in animal agriculture, aquaculture, and human medicine overlap (Cabello, 2006; Done et al., 2015). When bacteria are routinely exposed to antibiotics at low doses, bacterial strains with minor mutations are able to survive and rapidly reproduce, effectively self-selecting for greater antibiotic resistance (Chang et al., 2015). This risk is exacerbated in large host populations with less genetic diversity (e.g., in CAFOs) since the resistant bacterial strain will easily survive in other animals (Marshall and Levy,

2011). Most antibiotics are administered to animals through feed or water, leading to imprecise dosing (Love et al., 2011; Paulson and Zaoutis, 2015). AMR exposes humans to wide-ranging health risks by undermining the effectiveness of a key treatment pathway for bacterial infections: antibiotics. AMR genes can be passed horizontally within and between bacterial species, including to disease-causing bacteria in humans (Chang et al., 2015). AMR risks can be transmitted to humans via a wide variety of pathways. These include water contamination, the use of animal feces as a fertilizer, dispersion through the local environment (e.g., through wind dust), direct transmission from animals to their handlers — with farm operators and workers having shown signs of antibiotic resistance (Meena et al., 2015; Price et al., 2007; Zhang et al., 2009) — and direct transmission through food, i.e., when bacteria remain on meat and are not killed by cooking, or when animal feces is used as a fertilizer and bacterial residues remain on crops (CDC, 2013; McEachran et al., 2015).

Exposure to endocrine-disrupting chemicals (EDCs)

EDCs — chemicals that interfere with hormonal systems — are ubiquitous in food systems, and are generally seen to pose one of the greatest challenges for public health. These chemicals are found in: the pesticides used in conventionally grown crops; the hormones used in meat, poultry, and dairy production; the inside lining of canned foods and some plastic containers; compounds used as food preservatives; and, even in non-stick cookware⁸ (Wielogórska et al., 2015). Contamination of surface water with EDCs can result from agricultural runoff (Hanselman et al., 2003; Ying et al., 2002), fish hatcheries and dairy facilities (Kolodziej et al., 2004), and livestock operations (Orlando et al., 2004; Soto et al., 2004). There are close to 800 chemicals known or suspected to function as EDCs (WHO/UNEP, 2013). A substantial and growing body of evidence is converging upon the conclusion that exposure to EDCs contributes to increased chronic disease burdens (Gore et al., 2015; WHO/UNEP, 2013). Epidemiological research has identified several likely mechanisms⁹ that link long-term, low-dose pesticide exposure to higher risks of developing cancer in adults. Currently, the strongest accumulations of evidence (mechanistic, experimental, animal, and epidemiological) relate to bisphenol-A, phthalates, pesticides, persistent organic pollutants such as polychlorinated biphenyls, polybrominated diethyl ethers, and dioxins, and their links to obesity and diabetes (Newbold, 2010; Thayer et al., 2012; Gore et al., 2015), male reproduction (Li et al., 2011), female reproduction, hormone-sensitive cancers in females (Crain et al., 2008; Roy et al., 2009), prostate cancer (Chia et al., 2010), thyroid, and neurodevelopment and neuroendocrine systems (Gore et al., 2015; WHO/UNEP, 2013). Furthermore, both paternal and maternal exposure to EDCs in pesticides have been associated with adverse reproductive effects, including miscarriage, preterm birth, stillbirth, neonatal death, and foetal distress (Crisostomo and Molina, 2002; Jarrell et al., 1998; Kumar, 2004; PAN North America, 2016; Perera et al., 2003; Sanborn et al., 2007; Savitz et al., 1997). Neurotoxins are known to have strong adverse effects on the developing brain (Blainey et al., 2008),

EDCs — chemicals that interfere with hormonal systems — are ubiquitous in food systems, and are generally seen to pose one of the greatest challenges for public health.

and in-utero exposure has been linked to a range of developmental impacts (Berkowitz et al., 2004; Sanborn et al., 2007; Windham and Fenster, 2008; Wolff et al., 2007). Increased rates of cancer, and specifically brain tumours, have also been identified among the children of agricultural workers (Carozza et al., 2008; Efird et al., 2003; Feychting et al., 2001; van Wijngaarden, 2003).

Heavy metal contamination

Agricultural systems in many regions of the world contribute to heavy metal contamination of water bodies — with major health implications. Heavy metal toxicity can result in nervous system and brain damage, organ failure, and various types of cancer (Fernández-Luqueño et al., 2013). Heavy metals can also work as endocrine disruptors (see above) (Iavicoli et al., 2009). Potentially harmful effects can be generated from very low concentrations and from relatively short periods of exposure (Khetan, 2014). In China, the use of wastewater for irrigation, frequently in regions with intensive mining and smelting activities, has led to dangerous levels of heavy metals such as mercury, lead, and cadmium in soils and water sources, while the intensification of livestock agriculture has led to increased concentrations of arsenic, zinc, and copper (Lu et al., 2015). Arsenic contamination of groundwater in Pakistan and India is another example of large-scale heavy metal contamination to which agriculture is a major contributor; one estimate suggests that contaminated groundwater in the Indus Valley could affect more than 50 million people (Podgorski et al., 2017). The confluence of industrial activities and wastewater and sludge irrigation has also contributed to heavy metal pollution in other regions of the world (Fernández-Luqueño et al., 2013). Furthermore, many inorganic fertilizers and pesticides contain heavy metals that do not degrade easily and can lead to soil toxicity and water pollution (Gimeno-García et al., 1996). Finally, some fish species also accumulate heavy metals such as mercury during their lifetime (see Impact Channel 3: Contaminated, Unsafe, and Altered Foods).

Nitrogen-based air pollution

Agriculture has been identified as the largest contributor to air pollution in many regions of the world, including Europe, Russia, Turkey, Korea, Japan, and the Eastern United States (Lelieveld et al., 2015). Agricultural emissions of ammonia (NH₃) through livestock production and fertilizer use readily react with sulfur dioxide (SO₂) and nitrogen oxides (NO_x) to form inorganic PM_{2.5} (fine particulate matter composed of ammonium sulfate and ammonium nitrate) (Gu et al., 2014; Bauer et al., 2016). High exposure to this form of air pollution is associated with acute lower respiratory illness, cerebrovascular disease, ischaemic heart disease, chronic obstructive pulmonary disease, and lung cancer (Lelieveld et al., 2015). In particular, livestock operations that are located close to cities facilitate the mixing of agricultural NH₃ with SO₂ and NO_x from fossil fuel combustion (e.g., in urban transport systems), contributing to high levels of air pollution in densely populated urban areas (Gu et al., 2014; Paulot and Jacob, 2014).

ANNUAL COSTS RESULTING FROM EDC EXPOSURE

\$
217
BILLION
.....
EU — 1.28% of GDP

\$
340
BILLION
.....
USA — 2.33% of GDP

\$
42
BILLION
.....
USA — Pesticides alone

Transport-based air pollution and CO₂ emissions

Food systems also contribute significantly to air pollution and to climate change via the emissions incurred through the trucking and shipping of food and feed around the world. According to the WTO, agricultural products represent 9.5% of total merchandise trade (WTO, 2015); agricultural and fish commodities account for over 12% of global CO₂ emissions from international transport (Cristea et al., 2013). Extensive air- and road-based transport systems also increase air pollution from exhaust gases in airports and truck terminals, putting transport workers and other exposed populations at greater risk of conditions such as lung cancer, ischaemic heart disease, and excess upper and lower respiratory tract symptoms (Garshick et al., 2008; Laden et al., 2007; Tunnicliffe et al., 1999).

Who is affected?

The main populations vulnerable to health impacts from water-based pollution are low-income agricultural communities in developing countries that do not have access to potable water infrastructure and rely on contaminated water bodies and groundwater wells for drinking water (i.e., those in the most isolated areas). For example, in the Vietnamese Mekong delta, studies have found all types of drinking water sources (surface water, groundwater, water at public pumping stations, surface water chemically treated at household level, harvested rainwater, and bottled water) to be contaminated with pesticides at concentrations higher than key international benchmarks (Chau et al., 2015; Toan et al., 2013). Meanwhile, organochlorine pesticides — including highly toxic and now prohibited substances such as DDT and HCH — have been repeatedly detected in surface water, groundwater, and drinking water sources such as wells and hand pumps in India (Lari et al., 2014; Yadav et al., 2015) and Pakistan (Ali et al., 2014).

The International Livestock Research Institute (ILRI) mapped likely zoonoses hotspots across a range of zoonoses burden, poverty burden, and reliance on livestock, concluding that the regions with the most important hotspots were South Asia (particularly India), East and Central Africa (particularly Ethiopia and Nigeria), and Southeast Asia (specifically China and Indonesia) (ILRI et al., 2012). According to this review, only 19 countries (foremost Nigeria, Ethiopia, Tanzania, Togo, and India) bear 75% of the total global disease burden (ILRI et al., 2012). It also found strong evidence for a close association between poverty, livestock keeping, and zoonoses. Residents of densely populated urban and peri-urban centres in countries with expanding animal industries are in greater danger of zoonotic disease outbreaks than those in countries with effective public health and veterinarian services and experienced biosecurity personnel (Sundström et al., 2014).

However, some environmental contamination risks affect developed and developing countries alike, and are by no means limited to communities in direct

Agriculture has been identified as the largest contributor to air pollution in many regions of the world, including Europe, Russia, Turkey, Korea, Japan, and the Eastern United States.

proximity to intensive agricultural production. In the United States, increasing levels of nitrate pollution in public water sources make it difficult for some suppliers to provide drinking water at or below the legally mandated maximum concentration of nitrate (Iowa Environmental Council, 2016). For instance, the quality of drinking water in central Iowa and the state capital Des Moines as a result of upstream agricultural contamination has been increasingly questioned, and in 2015 became the subject of a lawsuit over damages payable by drainage districts and farmers (Eller, 2017). Meanwhile, air pollution potentially affects all citizens, since airborne particulate matter may drift between regions and even from one country to another, and poses the greatest risks in urban centres where agricultural pollution from the surrounding areas combines powerfully with emissions from industrial production and transport systems. Pregnant women, children, the elderly, and other subpopulations may have lower toxicity tolerance levels or be exposed to specific risks (such as methemoglobinemia or blue-baby syndrome).

Box 2

COUNTING THE HUMAN AND ECONOMIC COSTS OF ENVIRONMENTAL CONTAMINATION IN FOOD SYSTEMS: SELECT ESTIMATES

- Agriculture has been identified as the **largest contributor to air pollution** in many regions of the world, including **Europe, Russia, Turkey, Korea, Japan,** and the **Eastern United States** (Lelieveld et al., 2015).
- In several European countries, agricultural sources are responsible for as much as **40% of air pollution** and its associated health burden (Lelieveld et al., 2015).
- In China, the **10 cities with the highest PM_{2.5} levels** in 2013 were all surrounded by intensive agriculture facilities (Gu et al., 2014).
- It has been estimated that total population exposure to **EDCs** causes an annual health cost of **\$217 billion in the EU** (equivalent to 1.28% of EU Gross Domestic Product) (Trasande et al., 2016); and **\$340 billion in the US**, or 2.33% of GDP (Attina et al., 2016); another study estimated annual US EDC-related health costs incurred through pesticide exposure alone at **\$42 billion** (Attina et al., 2016).
- **Organophosphate pesticides** were estimated to produce the **costliest outcomes** in terms of EDC exposure in the EU (**\$121 billion per annum**) (Trasande et al., 2016).
- According to Lelieveld et al. (2015), on a global scale, **outdoor air pollution** leads to **3.3 million premature deaths annually**. After emissions from residential energy use such as heating and cooking, **agriculture is the second leading cause** of outdoor air pollution, accounting for **20% of the total disease burden**, or 664,100 deaths per annum. More than half of those premature deaths (395,390) were estimated to occur in China (Lelieveld et al., 2015).
- The Centers for Disease Control and Prevention reported that more than 2 million Americans become ill with **antimicrobial-resistant infections** each year, resulting in more than **23,000 deaths** (CDC, 2013).
- In the United States, antimicrobial-resistant infections have resulted in 8 million additional hospital days and health costs of **\$20 to \$34 billion annually**; the medical costs for each patient attributable to the antimicrobial resistance ranged from \$18,588 to \$29,069 (Paulson and Zaoutis, 2015; Roberts et al., 2009).

HOW MUCH DO WE KNOW ABOUT THESE IMPACTS, AND HOW WELL ARE THESE FOOD-HEALTH LINKAGES UNDERSTOOD?

In general, many of these problems have been well studied and documented, with evidence gathered at the relevant scope and scale. Still, some issues in this area (e.g., EDCs) have only recently gained significant scientific attention, and it is generally recognized that further research is required. Tracing these impacts back to specific sources, and proving causality in complex systems via long-term, low-level exposure, is inherently difficult (Gore et al., 2015) — although increasing evidence suggests the need for action (see Sections 3 and 4). Here we identify some specific challenges in consolidating evidence and understanding around environmental contamination pathways:

- **Incomplete testing**

Only a fraction of the many manufactured chemicals already introduced for commercial use have been tested for their potential EDC effects (WHO/UNEP, 2013). Indeed, not all suspected EDC effects can be tested, since testing methods for these effects are yet to be developed, validated, and agreed upon (Khetan, 2014). Robust exposure–response relationships are still scarce. Even for individual, well-studied substances, such as nitrates, the total negative effects of cell development and mutations are still under investigation. In general, there is little routine surveillance or testing of indirect exposure to chemicals through the food chain that is directly taken into account in chemical risk assessments. While the contribution of agriculture to air pollution has recently gained greater attention, relatively few toxicological studies have been undertaken to establish the health impacts of specific types of particulate matter (Paulot and Jacob, 2014). The US government does not systematically test or regulate air pollution around CAFOs — a big enough oversight to spark NGO lawsuits against the Environmental Protection Agency (EPA) (Valentine, 2015). The evidence base is also incomplete in terms of chronic exposure risks to fishers: while mortality statistics and causes have sometimes been documented, few broad and reliable studies have been dedicated to fishery-specific illnesses and chronic diseases (Matheson et al., 2001; Windle et al., 2008).

- **Using in vitro and animal studies**

Most of the data gathered so far on EDCs has been from laboratory studies of in vitro cells and animal models. For most substances, traditionally animal bioassays are extrapolated to humans, while, currently, computational and emerging alternative in vitro methods are under discussion for cost-saving measures. While results from in vitro and animal studies may be challenged as relevant to human populations, the similar function of hormone receptor systems in

humans and animals has been underlined (Khetan, 2014), suggesting that the current evidence may be robust in terms of predicting human response.

- **Levels of exposure and cumulative effects**

A key point of contestation regarding EDCs is whether they are harmful at the doses to which humans are exposed. A classical cause-effect inference is difficult to establish, given well-known characteristics of epidemiological studies (Ioannidis, 2016). Researchers have also pointed out the need for more studies on exposure to low doses of multiple pollutants and chemicals, and the implications of those interacting exposures for human health (Gore et al., 2015; Novak et al., 2011; Prüss-Ustün et al., 2011). Similarly, pollution with heavy metals and airborne particulate matter is inherently multidimensional and arises at the intersection of agricultural and industrial contamination, also leading to complexities in identifying specific sources of exposure.

- **Data gaps and difficulties capturing the complexity of livestock disease**

The clustering of recorded zoonotic disease events in the United States and Western Europe is likely to reflect historic surveillance and research differences rather than differences in occurrence rates. Little evidence exists that is comparable over time and that could allow for credible estimates of global changes in outbreak incidence (Newell et al., 2010). Using statistics on zoonotic disease to arrive at a “real” number of incidences requires sophisticated modelling approaches, which in turn rely on a number of assumptions and uncertainties (Morris, 2011).¹⁰ Though a number of review articles have attempted to estimate the current and potential human health burden of zoonotic disease transmission, there is still a large gap in terms of comprehensive, up-to-date global data suitable for quantitative meta-analysis (ILRI et al., 2012; Jones et al., 2013). Furthermore, standard modelling approaches struggle to capture the complexity of zoonotic disease transmission pathways and risks, which require an interdisciplinary and multi-scale understanding of the interactions between ecosystems, food systems, animal health, and human health (Cunningham et al., 2017). Similar challenges arise in terms of capturing antimicrobial resistance (AMR) risks. Since few countries have official registries that aggregate the utilization of antibiotics on food animal farms, models trying to estimate the impact of nontherapeutic antibiotic use in animal farming on human disease are often simplistic and inevitably rely on many assumptions (Marshall and Levy, 2011).

While results from in vitro and animal studies may be challenged as relevant to human populations, the similar function of hormone receptor systems in humans and animals has been underlined, suggesting that the current evidence may be robust in terms of predicting human response.

- **High turnover of exposed agricultural populations**

The long-term cohort studies that are required to consolidate understanding of these risks in agricultural populations — those most at risk and for whom the evidence is likely to be most conclusive — are made more difficult by the rapid turnover of farm labour, particularly migrant workers (see Impact Channel 1). Research focused explicitly on migrant farmworkers could help to elucidate the debate on low-dose exposures to pesticides and other environmental contaminants (Habib and Fathallah, 2012). Reporting by health authorities tends to be patchy for acute pesticide poisoning, let alone for continuous low-dose exposure or general work conditions (Cole, 2006).

- **Failure to disaggregate data**

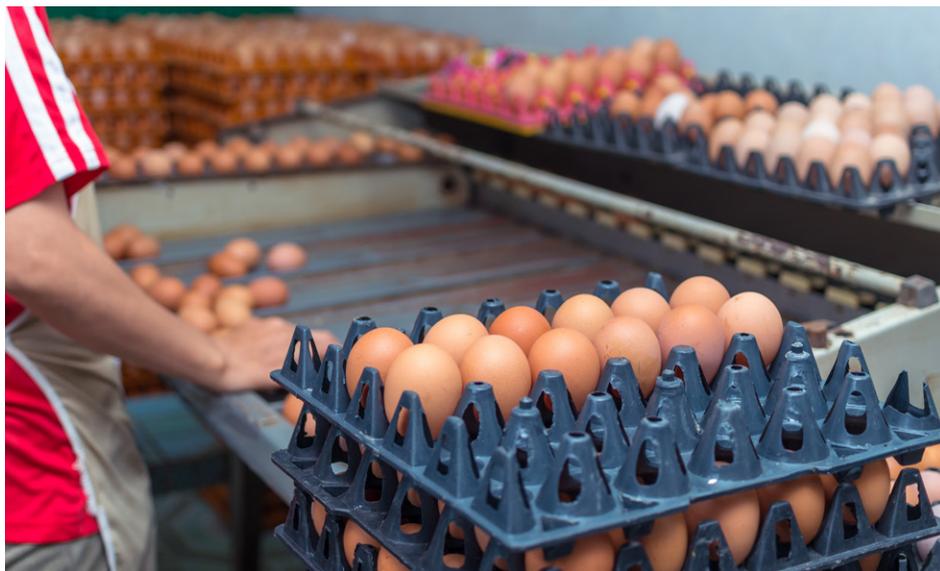
As described above, air pollution and climate change pose clear and present health risks, however, the full contribution of food systems to these trends is not always captured. While included in this analysis, transport-related emissions tend to be overlooked when evaluating the environmental and social impacts of food production; there is a failure to disaggregate data according to the type of goods being transported (Dalin and Rodríguez-Iturbe, 2016). Reporting systems often do not differentiate between zoonotic and non-zoonotic origins, and zoonoses are often conflated with other diseases and are thus under-reported (ILRI et al., 2012).

Fundamental questions are raised about how to capture the types of diffuse, chronic health risks generated by food systems, and how to politically prioritize impacts that are distant in time and space from the source.

Overall, while some estimates have been made regarding EDCs and other types of pollutants, the global burden of disease due to environmental pollution from food systems (from total exposure to water, air, or soil contamination) is still largely unknown, with incomplete data and information making for difficult analysis (Prüss-Ustün et al., 2011). Specific transmission pathways are hard to pinpoint given the inherent complexity of tracing pollutants and chemicals through ecosystems. The challenge in this regard is partly technical (e.g., relating to testing methodologies). However, it also raises more fundamental questions about how to capture the types of diffuse, chronic health risks generated by food systems, and how to politically prioritize impacts that are distant in time and space from the source (see Sections 3 and 4).



IMPACT CHANNEL 3 CONTAMINATED, UNSAFE, AND ALTERED FOODS



Ingestion of contaminated foods is perhaps the most direct and most documented type of health impact arising from food systems.

HOW DO HEALTH IMPACTS OCCUR THROUGH THIS CHANNEL?

Ingestion of contaminated foods is perhaps the most direct and most documented type of health impact arising from food systems. However, pathogenic contamination is not the only food safety concern faced by consumers. Specific foods may also pose health risks as a result of compositional alterations, novel elements, and effects of the preparation process. These pathways are described below.

Foodborne disease (FBD)

FBD agents fall into distinct categories — most importantly, bacteria (of which many have developed resistance to antimicrobials), viruses, chemical agents and toxins (e.g., EDCs), and parasites. These agents can lead to a variety of illnesses upon ingestion, ranging from gastrointestinal and diarrhoeal illnesses to influenza-like, respiratory, and neurological symptoms, allergies, and viral illnesses with significant mortality rates (Newell et al., 2010). On a global scale, the WHO estimates that the greatest source of FBD are diarrhoeal disease agents such as norovirus, non-typhoidal Salmonella, and Campylobacter, with Salmonella Typhi, Taenia solium, hepatitis A virus, and aflatoxin also representing important sources of food-related illnesses and fatalities (WHO, 2015a). Many bacterial, viral, and parasitic disease agents are zoonotic, i.e., transmitted through fecal matter or direct contact with animals or meat (Larsen et al., 2014; Newell et al., 2010; Slingenbergh et al., 2004; WHO, 2015a). As many as 63% of current pathogen species and 75% of emerging diseases are zoonotic in origin (Jones et al., 2013). In addition to the risks of zoonotic disease infection faced by livestock industry workers and general populations (see impact channels

1 and 2), zoonotic FBD outbreaks frequently originate in the consumption of meat, poultry, and animal products such as eggs and unpasteurized (or poorly pasteurized) milk, cheeses, and other dairy (Doyle et al., 2015; Painter et al., 2013). Poultry has been identified as the commodity that accounts for most deaths resulting from foodborne pathogens (mainly Salmonella and Listeria) in the United States, followed by dairy (Painter et al., 2013), partly reflecting the high consumption of these items. Eggs have been found to be responsible for an estimated 58% of salmonellosis cases in Europe, while an estimated 29% of campylobacteriosis cases were linked to the consumption of poultry meat (Pires et al., 2010). In the EU, the food- and water-borne pathogens causing the highest disease burden are Campylobacter, non-typhoidal Salmonella, Shiga toxin-producing E. coli, as well as Listeria (Cassini et al., 2016).

Fresh fruit and vegetables have been increasingly prevalent in foodborne illness outbreaks, particularly in light of recent trends toward consumption of raw produce, on which disease agents are more likely to survive and be ingested by humans (Strawn et al., 2013). Many of the pathogens contaminating plant-based products are also zoonotic in origin. These pathogens can spread through a variety of pathways, e.g., the use of untreated manure on cropland, contaminated irrigation water, runoff from livestock operations, wildlife intrusion (Strawn et al., 2013), the use of contaminated seeds or machinery in the pre-harvest phase, as well as cross-contamination due to insufficient hygiene during handling, processing, and transport (Yeni et al., 2016). Some 46% of US foodborne illnesses between 1998–2008 have been attributed to fresh fruit and vegetables, particularly outbreaks of norovirus and E. coli (Painter et al., 2013). Over this period, leafy vegetables accounted for 22% of illnesses, more than any other commodity (Painter et al., 2013). In Europe, leafy greens eaten as salad were a frequent cause of Salmonella and norovirus infections (Callejon et al., 2015); sprouts, seeds, and nuts were also found to be common sources of foodborne pathogens (Yeni et al., 2016), with alfalfa sprouts (grown from contaminated seeds) at the heart of the largest outbreak of E. coli in recent history, the 2011 outbreak in Germany that led to 53 deaths (Manitz et al., 2014).

Who is affected by FBD and how?

Beyond production-based and environmental pathways, food contamination also occurs through unsanitary handling and preparation of food — inside and outside the home. In spite of detailed best practice guidance, human error among food producers and processors, restaurants, and food service institutions still accounts for most cases of contamination (Gould et al., 2015; Newell et al., 2010), including food businesses with superior ratings from third-party audits (Powell et al., 2013). In many countries, diets are shifting to include greater shares of out-of-home consumption and the use of semi-prepared ingredients, amplifying these transmission channels (Callejon et al., 2015; Doyle et al., 2015; Gould et al., 2015). The role and responsibility of the consumer has often been emphasized, with safe food-handling and preparation practices

seen as key to minimizing FBD risks (Doyle et al., 2015). The WHO highlights that low-income regions of the world are disproportionately affected by FBD (WHO, 2015a). Though all final consumers are exposed to foodborne pathogens, the probability of contracting illnesses with serious consequences is higher for vulnerable populations such as children, pregnant women, the elderly, and immune-compromised individuals (Lund, 2015; Yeni et al., 2016). Though representing only 9% of the global population, children under five incur 43% of the disease burden of contaminated food (WHO, 2015a).

Biotoxins

Another source of FBD, particularly via seafood, is the presence of biotoxins: toxic substances with a biological origin, such as specific algae that may be ingested and accumulate in fish (Painter et al., 2013). Biotoxins represent a persistent and complex health challenge in the seafood chain, given the difficulties in preventing pre-harvest contamination and identifying toxin-carrying seafood, and given the heat-stable nature of the toxins — meaning that safe cooking and preparation may not reduce the risks (Huss et al., 2000). Ciguatera (causing gastrointestinal and neurological effects) has become the most frequent seafood-borne illness worldwide, accounting for 50,000 to 500,000 cases per year, and now spreading to previously unaffected regions, e.g., the Mediterranean (Mattei et al., 2014; Visciano et al., 2016). Climate change and warming oceans are extending the range of marine biotoxins and increasing the frequency of harmful algal blooms, raising the risks of increased biotoxin-related seafood-borne illness outbreaks in the future (Canyon et al., 2016; Visciano et al., 2016).

Chemical contamination of foods

Many of the environmental contaminants explored in Impact Channel 2 (environmental contamination) may also be sources of direct food contamination, entering foods via pesticide residues and other channels (e.g., preparation involving contaminated water). Food-based EDC risks add to the general burden of EDC exposure in food and farming systems, and the severe health risks it brings (see Impact Channel 2). The bioaccumulation of mercury and lead in fish is another example of food-based chemical contamination. Meanwhile, chemical compounds found in foods and exacerbated through elements of food preparation can also present significant human health risks. For example, levels of acrylamide, a probable carcinogen (IARC, 1994), can be increased through over-cooking of starchy products in the home, in processing plants, or in food service sites (e.g., restaurants, food trucks) (Xu et al., 2014).

Food processing, food composition, and allergenicity

Industrial food processing methods such as irradiation, homogenization, thermal processing, fermentation, and hydrolysis affect the molecular composition of macronutrients (particularly proteins) and micronutrients present in foods such as dairy products, eggs, wheat, tree nuts, and shellfish (Verhoeckx et al., 2015; AFFA, 2015). Food allergies and food intolerances have been directly

THE COSTS OF FOOD CONTAMINATION

**600
MILLION
ILLNESSES**

**420,000
DEATHS**

.....
Global impact of 31 most common foodborne hazards — 2010

**\$14
BILLION**

.....
Illness-related costs of 14 most common pathogens — Annually

linked to food processing and resulting changes in molecular composition (Vanga et al., 2015). Both the prevalence and perceived allergen threat by the general population have increased over the past few decades (De Blok et al., 2007; Lack, 2008; Prescott et al., 2013; Savage and Johns, 2015). However, evidence on the causal links is still limited (see below). Some studies have also associated genetically modified crops with increased allergenic risks.

Nanoparticles

Recent evidence suggests that the nanoparticles now included in a range of processed foods may be able to cross cellular barriers, therefore posing major carcinogenic and gastro-enteric risks (Chaudhry et al., 2008; Shi et al., 2013). The micro- and nanoparticles most commonly found to date are titanium dioxide (TiO₂) and aluminosilicates, which are added as anti-caking agents to powdered and granular foods (Chaudhry et al., 2008). Though these substances have traditionally been regarded as safe for human consumption due to their stable and inert characteristics, their use as nanoparticles with smaller size and larger surface area has called these assumptions into question, leading the International Agency for Research on Cancer (IARC) to reclassify TiO₂ nanoparticles as “possible carcinogenic to humans” (Chaudhry et al., 2008; Shi et al., 2013; Skocaj et al., 2011).

Box 3

COUNTING THE HUMAN AND ECONOMIC COSTS OF FOOD CONTAMINATION: SELECT ESTIMATES

- The ILRI assessed 56 zoonoses in its overview study, relying on WHO Global Health Burden data to estimate that they are responsible for about **2.5 billion cases of human illness** and **2.7 million human deaths** per year (ILRI et al., 2012).
- In low-income countries, **27% of livestock** displayed signs of current or past infection with bacterial foodborne disease (ILRI et al., 2012).
- The WHO Foodborne Disease Burden Epidemiology Reference Group (FERG) estimates that the 31 most common foodborne hazards were the cause of **600 million foodborne illnesses** and **420,000 deaths globally** in 2010. In total, the global burden of foodborne disease by these 31 hazards was estimated at **33 million Disability Adjusted Life Years (DALYs)** (WHO, 2015b).
- The greatest burden — **18 million DALYs** — was attributed to **foodborne diarrhoeal disease agents**, particularly non-typhoidal Salmonella enterica, and enteropathogenic E. coli (EPEC) (WHO, 2015b).
- In the United States, from 1998 to 2008, an estimated **47.8 million illnesses, 127,839 hospitalizations, and 3,037 deaths** per year have been attributed to foodborne pathways (Morris, 2011; Scallan et al., 2011a, 2011b).
- The 14 most frequently occurring pathogens (which represent 95% of illnesses and 98% of deaths in Scallan et al.’s [2011b] study) are estimated to cause **\$14 billion of illness-related costs** and a loss of **61,000 QALYs per year**. Five pathogens account for approximately 90% of this burden: non-typhoidal Salmonella enterica (\$3.3 billion; 17,000 QALYs), Campylobacter spp. (\$1.7 billion; 13,300 QALYs), Listeria monocytogenes (\$2.6 billion; 9,400 QALYs), Toxoplasma gondii (\$3 billion; 11,000 QALYs), and norovirus (\$2 billion; 5,000 QALYs) (Hoffmann et al., 2012).
- It is estimated that food- and water-borne diseases cause just over **2,000 deaths** and cost **19.14 DALYs/100,000 inhabitants** per year in the EU/EEA. Campylobacteriosis was the disease with the highest burden in the EU/EEA with 8.20 DALYs per 100,000 citizens, followed by salmonellosis with 3.96 and infection with Shiga toxin-producing E. coli (STEC) with 2.08 (UI: 2.59–3.21) DALY. The three diseases represented more than 75% of the European food- and water-borne disease burden (Cassini et al., 2016).

HOW MUCH DO WE KNOW ABOUT THESE IMPACTS AND HOW WELL ARE THESE FOOD-HEALTH LINKAGES UNDERSTOOD?

Some clear gaps in the knowledge base on contaminated, unsafe, and altered foods can be identified, primarily reflecting geographical differences in coverage and quality of reporting and detection systems:

- **Data gaps between countries and over time**

Only a handful of countries collect reliable data on the reported incidence of FBD and the resulting health impacts. Even when such data is available, only a small percentage of foodborne illnesses and hospitalizations is confirmed by laboratories and reported to public health agencies. The data gaps are particularly large in developing nations where the health burden of those diseases is estimated to be highest (WHO, 2015a). The WHO Initiative to Estimate the Global Burden of Foodborne Diseases, launched in 2015, seeks to bridge this gap.

Only a handful of countries collect reliable data on the reported incidence of foodborne disease and their related public health impact.

- **Difficulties disaggregating the data**

Detection measures for pathogens vary in their sophistication, and foodborne viruses frequently escape food inspections, making the attribution of the proportion of viral illness to foodborne sources highly complex (Newell et al., 2010).

- **Insufficient data on nanoparticle exposure**

There is a continued lack of reliable data on the absorption, distribution, excretion, and toxicity of oral exposure to nanoparticles. Although nanoparticles are already ubiquitous in food products, researchers have recommended caution in their use until relevant toxicological and human exposure data are obtained in order to enable reliable risk assessment (Skocaj et al., 2011).

- **Generally Regarded as Safe (GRAS) food substances**

Under the United States' Food Additive Amendments of the Federal Food, Drug, and Cosmetic Act (FFDCA), for all food additives (with the exception of colour additives), it is the responsibility of manufacturers to conclude whether new substances are generally regarded as safe (GRAS) by scientific experts and the available evidence. If they decide that sufficient evidence exists for a substance to be determined GRAS, they are allowed to market the substance for that particular use without the FDA's review and approval (FDA, 2014). Companies may, but do not have to, submit their evaluation to an FDA review through the GRAS notification process (FDA, 2014). This procedure differs from food additive regulation in most other countries (e.g., Argentina, Australia/New Zealand, Brazil, Canada, China, the European Union, Japan, and Mexico) where any food additive that is not yet on a positive list of

permitted ingredients has to be submitted for approval by the appropriate regulatory authority (Magnuson et al., 2013). Consequently, of the approximately 6200 current affirmative safety decisions on food additives in the United States, 60% were made by manufacturers and trade associations rather than federal agencies (Neltner et al., 2011). Furthermore, Magnuson et al. (2013, p. 1194) point out that “as USFDA notification of the GRAS determination is voluntary, there is no publicly available list of the uses of substances that have been ‘self-determined’ to be GRAS and thus no opportunity for public scrutiny of safety decisions,” including those regarding nanoparticles and other novel substances. Neltner et al. (2011) estimated that by 2011 as many as 1000 manufacturer safety decisions, one-sixth of the total, had never been reported to the FDA or the public.

It is therefore clear that foodborne disease remains a major source of health risk around the world, although it is under-reported in many places. While the immediate source of FBD outbreaks is often known, there is far less consensus on the underlying causes (i.e., which food system practices generate the greatest risks), with different problem framings and different types of solutions continuing to be emphasized (see Section 3). Further risks relating to altered foods may also be considerable — although major gaps remain in current capacities to identify, assess the safety of, and regulate new elements coming into the food chain.



IMPACT CHANNEL 4 UNHEALTHY DIETARY PATTERNS



Unhealthy dietary patterns have become increasingly prevalent over recent decades — a trend that has been accompanied by increasing rates of overweight, obesity, and noncommunicable diseases worldwide.

HOW DO HEALTH IMPACTS OCCUR THROUGH THIS CHANNEL?

This impact channel concerns the effects of dietary patterns on health, beyond the questions of undernutrition that will be addressed in Impact Channel 5: Food Insecurity. The diet-related health impacts described below all manifest themselves in raised risks of obesity and/or noncommunicable diseases (NCDs). Indeed, the growing prevalence of obesity is a global health concern as it forecasts increasing incidence of several debilitating diseases, including type 2 diabetes, hypertension, coronary heart disease, metabolic syndrome, respiratory conditions, cancer, osteoarthritis, and reproductive, gall bladder, and liver diseases (Butland et al., 2007; Grundy, 2016; Wang et al., 2011).

While some specific high-risk foods are identified below, it is diets in their entirety and overall balance that are increasingly being associated with health impacts. Healthy diets are generally considered to include a diversity of nutrient-rich foods, such as vegetables, fruits, whole grains, pulses (beans, legumes, nuts and seeds), with (for non-vegetarians or vegans) modest amounts of meat and dairy and unsaturated vegetable oils (GLOPAN, 2016). Conversely, unhealthy dietary patterns are characterized by foods high in added sugars, sodium, saturated fat, and trans fat; and low in fruits, vegetables, pulses, whole grains, and nuts. There is consistent evidence that healthy dietary patterns as described above are associated with lower risks of cardiovascular disease (USDA, 2014). Meanwhile, unhealthy dietary patterns have been identified as a risk factor for a range of NCDs, both directly and by contributing to obesity (Kaveeshwar and Cornwall, 2014). Unhealthy dietary patterns have become

increasingly prevalent over recent decades — a trend that has been accompanied by increasing rates of overweight, obesity, and noncommunicable diseases (NCDs) worldwide.

Excess energy intake (i.e., energy-dense unhealthy dietary patterns) has been identified as the most important dietary factor in relation to weight gain and the development of obesity (Roberts et al., 2002). Specific foods have been identified as key contributors to increased energy intake and thus as drivers of obesity and associated NCDs; in other cases, increased NCD risks have been associated with high intake of specific foods and nutrients, irrespective of broader dietary patterns and total energy intake. Some key examples follow:

- Increased consumption of sugar-sweetened beverages (SSB)** has been singled out as a significant contributor to the obesity epidemic in recent years (French and Morris, 2006; Malik et al., 2006; Popkin and Hawkes, 2016; Taylor and Jacobson, 2016; Vartanian et al., 2007; WHO/FAO, 2002; World Cancer Research Fund/AICR, 2007). By one estimate, soda had become the single largest energy source in the American diet by 2006 (Mattes, 2006). The main causal mechanism linking SSBs to weight gain is that the consumption of liquid calories does not induce corresponding feelings of satiety, leading to incomplete compensatory reduction in energy intake at subsequent meals (Malik et al., 2010). A further potential pathway is that rapid spikes in blood glucose and insulin after SSB consumption may contribute to a high dietary glycemic load (GL), which may induce glucose intolerance, insulin resistance, and inflammation (Malik et al., 2010). Recent systematic reviews have therefore paved the way for SSBs to be identified as a major risk factor for long-term weight gain and noncommunicable diseases (Hu and Malik, 2010; Malik et al., 2006; Morenga et al., 2013; Sonestedt et al., 2012; Swinburn et al., 2004), including cardiovascular mortality (Thornley et al., 2012; Yang et al., 2014) and type 2 diabetes (Basu et al., 2013). More broadly, high dietary intake of added sugars has been associated with hypertension, high blood cholesterol, higher blood pressure, and type 2 diabetes, leading the WHO to recommend limiting the consumption of free sugars to 5% of total energy intake (WHO, 2015b).
- Overconsumption of animal products** has been connected with heart disease, diabetes, and various cancers (Feskens et al., 2013; Green et al., 2016; Melnik, 2012; Oggioni et al., 2015; Tilman and Clark, 2014). Some studies have identified excess insulin-like growth factor (IGF-1) as a driver of cancer cell proliferation in humans, e.g., in breast cancer, and have linked high IGF-1 levels to animal protein regardless of total protein intake levels (Endogenous Hormones and Breast Cancer Collaborative Group et al., 2010; Rowlands et al., 2009; Y. Zhang et al.,

ECONOMIC IMPACT OF OBESITY

ECONOMIC LOSSES DUE TO NDCS

\$ 7

TRILLION

Low & middle-income countries — 2011–2025

COST TO IMPLEMENT INTERVENTIONS

\$ 11.2
BILLION

USA — Annually

2010). Specific types of meat have also been associated with increased NCD risks. Following reclassification in 2015, the WHO considers that processed meats (such as hot dogs, ham, sausages, corned beef, canned meat, and meat-based sauces) may cause colorectal cancer and are associated with stomach cancer (IARC/WHO, 2015).¹¹ It also considers that red meat (i.e., all muscle meat, such as beef, veal, pork, and lamb) is linked to colorectal, pancreatic, and prostate cancers (IARC/WHO, 2015).

- **High sodium intakes** are associated with higher blood pressure and hypertension (National Research Council, 2015). Globally, 1.7 million annual deaths from cardiovascular causes have been attributed to excess sodium intake (WHO, 2014).
- A number of recent studies suggest that **high consumption of saturated fats** is associated with increased risk of coronary heart disease and diabetes (Forouhi et al., 2016; Zong et al., 2016; Chen et al., 2017). However, the evidence in this area remains highly contested (see below).
- **The negative health impacts of trans fatty acids (TFAs)** — a type of unsaturated vegetable fat typically found in manufactured cooking oils — are now the subject of broad consensus, with legal limits and bans on TFAs introduced in Denmark, Austria, Switzerland, Iceland, Hungary, Norway, and Latvia (Stender et al., 2016). In the United States, where trans-fat bans are already in place in New York City and the state of California, a nation-wide ban on partially hydrogenated oils will come into effect in 2018 (FDA, 2015).
- Overall, **the increasing proportion of ultra-processed foods in diets** has been identified as a driver of excess energy intake (Monteiro, 2010). Ultra-processed foods are defined as “industrial formulations which, besides salt, sugar, oils, and fats, include substances not used in culinary preparations, in particular additives used to imitate sensorial qualities of minimally processed foods and their culinary preparations” (Steele et al., 2016). Often consumed in large portion sizes, and by nature high in fats, sugar, and salt, ultra-processed foods have been associated with obesity, chronic diseases, and other markers of poor health (Ludwig, 2011; Monteiro et al., 2012; Moodie et al., 2013; Moreira et al., 2015; Stuckler et al., 2012).
- **High fruit and vegetable intake**, meanwhile, is generally seen to reduce NCD risks. For example, it has been inversely related to the incidence of myocardial infarction and stroke (National Research Council, 2015).

HOW MUCH DO WE KNOW ABOUT THESE IMPACTS, AND HOW WELL ARE THESE FOOD-HEALTH LINKAGES UNDERSTOOD?

Diets and nutrition have been the subject of extensive attention in scientific investigation, media coverage, and public debate for decades. Consensus is growing around key points in the evidence base, and key understandings are being built. There is now strong agreement that dietary patterns play an important role in human health. There is also a widespread understanding about what healthy diets and unhealthy diets look like, although there are still some outstanding disagreements on the role of particular food items and nutrients, such as the role of animal fat in a healthy diet. And there seems to be increasing consensus on the need to look beyond the energy balance (calories in/out) and to consider specific dietary components and how they interact (i.e., the impacts of different types of foods on blood sugar or hormonal factors, and the diverse determinants of metabolic rate) in order to understand what determines an individual's weight, dietary status, and the resulting health implications. However, views continue to diverge around the collective strength and validity of an immense evidence base, and where responsibility for healthy diets (and the levers for change) ultimately lies. These contestations are illustrated by the following points:

- **Disputed role of saturated fats**

The links between saturated fat and NCDs, and therefore the health impacts of meat and dairy consumption, remain highly contested. There is growing consensus in the public health community that current levels of saturated fat consumption in developed countries are too high and generate health risks, for example, more than 90% of the European Union population consumes higher levels of total and saturated fat than WHO recommendations (Schäfer Elinder et al., 2006). However, while studies have associated saturated fats with cardiovascular disease (CVD) and diabetes (see above), there is still significant debate over the broader impacts of dairy consumption, and how to translate this into dietary recommendations. For example, some studies show little to no correlation between dairy and increased risk of overweight and NCDs (Lawrence, 2013; German, 2009), while others have highlighted the possible positive effects of dairy on lowering incidence of type 2 diabetes and cardiovascular disease (Mozaffarian, 2014). This has led to calls for further research to clarify the role of dairy and saturated fat in contributing to NCDs, and for more caution regarding recommendations on fat consumption that are made irrespective of the types of products consumed (Arstrup et al., 2010; German, 2009).

- **Multifactoriality of diet-related conditions**

Some uncertainty and contestation centres on methodological challenges in pinpointing causality where diet-related impacts are

ANNUAL EXPENDITURE ON DIABETES

12%
GLOBAL
HEALTHCARE
EXPENDITURE
SPENT ON
DIABETES

\$
245
BILLION

.....
USA — 2012

\$
673
BILLION

.....
Globally — 2010

concerned. Indeed, all diet-related conditions are complex and multifactorial, with the incidence of NCDs highly contingent on a person's general health status, and obesity acting as a gateway to a variety of health conditions. For example, high consumption of SSBs may be a marker of a generally poor-quality diet, i.e., a diet characterized by higher total consumption of various (unhealthy) foods and lower consumption of fruits and vegetables (Liebman et al., 2003; McCarthy et al., 2006). Meanwhile, obesogenic diets and lack of physical activity often co-exist, making it difficult to isolate their relative contributions (Giskes et al., 2011). Furthermore, foods may have beneficial or harmful effects at different doses in different combinations and different individual (genetic and physical) circumstances (National Research Council, 2015). Controlling for the various factors is a major challenge, as double-blinded, placebo-controlled, randomized controlled trials (RCTs), often used in medicine to isolate a treatment and measure its health effect, are not always viable or appropriate in nutrition studies. While a number of influential global reports asserted that SSBs play a key role in the etiology of obesity (WHO/FAO, 2003; World Cancer Research Fund, 2007), some critical reviews of the evidence tended to be more cautious, highlighting methodological weaknesses in many studies (Gibson, 2008). The complexities in determining causality left ample space for interpretation. Some critical reviews described the evidence on SSBs as “not conclusive” (Bachman et al., 2006), “equivocal” (Forshee et al., 2008; Pereira, 2006), or just “probable” (World Cancer Research Fund/AICR, 2007). According to Anderson (2006), the associations between SSB and obesity had to be viewed as circumstantial, and therefore did not support cause and effect conclusions. More recently, however, the association between SSB consumption and poor health has received more scientific support. While a 2015 review of studies on SSBs and obesity found that more than two-thirds had at least one methodological weakness potentially compromising the conclusion, the majority of studies with strong methodology—including two out of three randomized controlled trials (RCTs)—*did* demonstrate a positive association between SSB intake and risk of overweight or obesity, especially among overweight children (Della Torre et al., 2015). Still, despite the fact that consumption of SSB has been identified as a strong risk factor for long-term weight gain and noncommunicable diseases, cardiovascular mortality, and type 2 diabetes (Malik et al., 2010), some critics continue to argue that it is unfair to single out one type of food as a driver of obesity (Brownell and Frieden, 2009).

- **Industry-sponsored nutrition science muddying the waters**
Question marks over the credibility of scientific research in this field — and the role of the large corporations in the food industry — represent

a further challenge in terms of building comprehensive and shared understandings. The empirical evidence on the influence of industry-backed studies in shaping understandings — and ultimately policy — is largest for medical, pharmaceutical, and tobacco research. However, emerging research supports the hypothesis that some corporations in the agri-food industry operate in a similar fashion and have meaningfully impacted debates around nutrition (Brownell and Warner, 2009; Nestle, 2016; The PLoS Medicine Editors, 2012). Lesser et al. (2007) show in a review of nutrition research on soft drinks, juice, and milk that the funding source may have a significant impact on study conclusions, with 0% of industry-backed studies reporting an unfavourable outcome (as compared to 37% of publically funded articles). Major discrepancies have been found between the results of industry-funded and non-industry-funded studies (including systematic reviews) on the health impacts of sugar consumption and SSBs (Bes-Rastrollo et al., 2013; Vartanian et al., 2007). Explicit attempts from the 1960s onwards to divert attention from sugar onto fat as a heart disease risk factor were recently uncovered, and are seen to have significantly derailed decades of medical research around sugar (Kearns et al., 2016; O'Connor, 2016). Popkin and Hawkes (2016, p. 175) conclude that it is only studies funded by the sugar and beverage industries that continue to cast doubt on the evidence — shown through extensive meta-analyses — of substantial weight gain and cardiometabolic risks from SSBs. Industry funding of professional associations has also been alleged to heavily influence the framing of prominent public debates (Nestle, 2013; Simon, 2013, 2015). For example, the scientific objectivity of the American Society for Nutrition (ASN) and the Academy of Nutrition and Dietetics (AND) has been called into question on the basis of strong ties to the food and beverage industry (Simon, 2013, 2015). This has major implications since the ASN is the publisher of three widely read nutrition science journals, the *American Journal of Clinical Nutrition*, the *Journal of Nutrition*, and *Advances in Nutrition*, in which many industry-funded studies are published. Meanwhile, the “Nutrition Fact Sheets” produced and publicized by the American Dietetic Association (ADA) have been called into question on the grounds of industry partners having paid for the right to co-write them (Brownell and Warner, 2009).

- **Shifting attention to the “food environment”**

Tensions can also be observed when considering drivers of unhealthy/healthy diets. For decades, responsibility for diets has been placed at the door of individuals. Over recent years this view has been challenged. Consumer food choices have been increasingly understood in the context of the “food environment”: the “collective physical, economic, policy, and sociocultural surroundings, opportunities, and conditions that influence people’s food and beverage choices and

THE SPIRALLING COSTS OF OBESITY

\$ **190**
BILLION

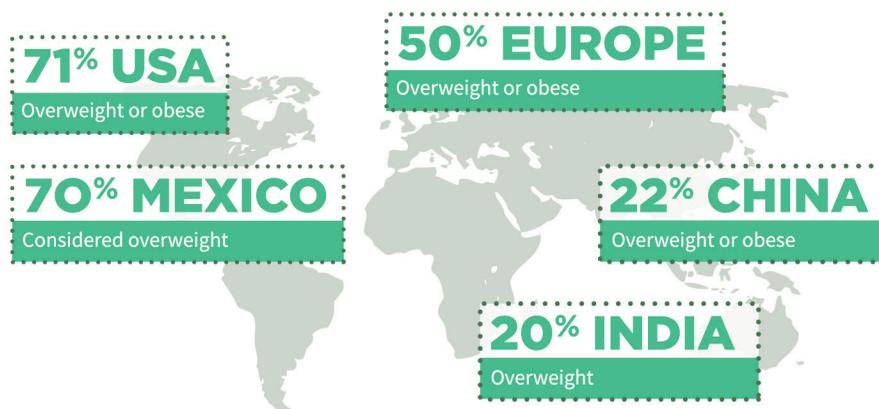
.....
2005

X2

.....
Healthcare costs of
overweight & obesity to
double each decade

16-18%
OF TOTAL
HEALTH
EXPENDITURE
BY 2030.

GLOBAL RATES OF OVERWEIGHT & OBESITY



nutritional status” (Food Foundation, 2016). From this perspective, the availability of specific types of food in specific settings (e.g., schools, neighbourhoods) and a range of socio-economic and lifestyle factors (e.g., the growth of out-of-home dining) have been emphasized as drivers of dietary shifts, e.g., toward higher consumption of prepared foods high in added sugars, sodium, and fats (Caraher and Coveney, 2004; Drewnowski et al., 2004; Lake and Townshend, 2006; Lobstein et al., 2004; Neff et al., 2009; Swinburn et al., 1999). Vicious cycles have been identified within unhealthy food environments. For example, increased consumption of highly processed foods has been found to contribute to — and be reinforced by — a gradual loss of food skills and food knowledge, reduced personal creativity and control over daily meals, and inhibited awareness of food ingredients and their health value (Engler-Stringer, 2010; Jaffe and Gertler, 2006; Lang et al., 2001; Larson et al., 2006; Smith et al., 2013). Refocusing attention on the food environment therefore significantly changes the framing of the diet question, leading to different types of inquiry and different types of policy. This shift has not been complete or systematic (see Section 3).

A proliferation of ambitious policy actions in the past few years suggests that the public health challenge around overweight and obesity is being taken increasingly seriously. For example, soda taxes have been put in place in several countries and jurisdictions (such as Mexico, Hungary, India, and the United Kingdom). Meanwhile, ambitious food-based dietary guidelines have been introduced, notably in Brazil. However, while the quantity of evidence is extensive, major challenges clearly remain in terms of forging the understandings that will pave the way for sustained action to tackle the obesity and NCD epidemics.

Box 4

COUNTING THE HUMAN AND ECONOMIC COSTS OF UNHEALTHY DIETS: SELECT ESTIMATES

- Overweight and obesity have reached **epidemic levels** in many countries (Chan, 2016; WHO, 2015a). If trends continue their trajectory, **almost half of the world's population will be overweight or obese** by 2030 (McKinsey Global Institute, 2014).
- According to a recent worldwide assessment, from 1975 to 2014 the global age-standardized mean BMI increased **from 21.7 kg/m² to 24.2 kg/m² in men**, and **from 22.1 kg/m² to 24.4 kg/m² in women** (NCD-RisC, 2016).
- Since 1980, the worldwide **prevalence of obesity has more than doubled** (Chan, 2016), with **39% of adults estimated to be overweight and 13% to be obese** (WHO, 2015a). Worldwide, it is estimated that the number of obese adults grew from 105 million in 1974 to 640 million by 2014 (Chan, 2016).
- **41 million children under age 5** and **170 million under age 18** are now overweight (IFPRI, 2016).
- Regionally, the **Middle East, North Africa, Central America, and Islands in the Caribbean and Pacific all have exceptionally high rates of overweight and obesity** (above 44%) (Ng et al., 2014); the highest regional mean age-standardized BMI in 2014 was found in **Polynesia and Micronesia** (29.2 kg/m² in men and 32.2 kg/m² in women) (NCD-RisC, 2016). Nearly 20% of India's population is now overweight; 300 million Chinese are obese (Chan, 2016); 7 out of 10 Mexicans are considered overweight, with a third of them clinically obese (Chan, 2016; OECD, 2014)
- In the USA, **71% of people** are either overweight or obese (NCHS, 2016). It is estimated that obese individuals incur **30% higher medical costs** than their normal weight counterparts (as cited in Wang et al., 2011). In that country, studies show that when one person in a household is obese, the household faces additional annual healthcare costs equivalent to **8% of its annual income** (IFPRI, 2016).
- According to one estimate, **\$190 billion** was spent on obesity-related medical care in 2005 (Cawley and Meyerhoefer, 2012), but the full economic burden is even higher as this figure only accounts for direct healthcare costs (Lehnert et al., 2013). Total healthcare costs attributable to overweight and obesity are projected to double every decade to account for **16–18% of total healthcare expenditure** by 2030 (Wang et al., 2008, as cited in Wang et al., 2011).
- In **Brazil**, in 2010, **57% of adult males and 43% of females were overweight** or obese (Bahia et al., 2012). The healthcare costs associated with overweight and obesity were estimated between **\$2.1 billion** (Bahia et al., 2012) and **\$5.8 billion** (Rtveladze et al., 2013).
- In Europe, **50% of people** are either overweight or obese (WHO, 2015a).
- In England, the cost of overweight and obesity in 2002 was estimated to be **£7 billion**, which included direct costs of treatment, state benefits, and lost earnings due to loss of productivity (Foresight, 2007).
- Noncommunicable diseases are now the leading cause of death globally, with **68% (38 million)** of all deaths in 2012 being related to **NCDs** (WHO, 2014a). More than 40% of these deaths occurred prematurely (before the age of 70) and would have likely been preventable with appropriate lifestyle changes, including healthier diets: **73%** of all NCD deaths, and **82%** of premature deaths, took place in low- and middle-income countries (WHO, 2014a).

Box 4 (CONT.)

COUNTING THE HUMAN AND ECONOMIC COSTS OF UNHEALTHY DIETS: SELECT ESTIMATES

- The main NCDs linked with unhealthy diets are **diabetes, cardiovascular diseases**, and some **cancers**.
 - Diabetes is closely linked with the rise of obesity. The global prevalence of diabetes is estimated to be **6.4%** among adults aged 20–79 years. Between 2010 and 2030, there is projected to be a **69% increase** in the numbers of adults with diabetes in developing countries and a **20% increase** in developed countries (Shaw et al., 2010).
 - The International Diabetes Federation estimates that **45%** of adults with diabetes are **undiagnosed** and that by 2040, 1 in 10 adults globally will have type 2 diabetes (IDF, 2016).
 - The top three countries with the greatest numbers of people living with diabetes are **China** (110 million), **India** (69 million), and the **United States** (29 million) (IDF, 2016). In China, a diagnosis of diabetes results in an annual **16.3% loss of income** (IFPRI, 2016).
 - Type 2 diabetes now increasingly affects younger people, resulting in a lifetime of treatment of the disease and its complications. The American Diabetes Association estimates that the cost of diabetes in the United States in 2012 was **\$245 billion**, including \$176 billion in medical costs and \$69 billion in reduced productivity (American Diabetes Association, 2013). **Twelve percent** of global expenditure on healthcare (\$673 billion annually) is spent on **diabetes** (P. Zhang et al., 2010).
 - Some forms of **cancers** are also associated with diets. In 2012, there were **14 million** new cases of cancer, and **8.2 million** cancer-related deaths globally (WHO, 2014b). Cancer accounted for **16.7%** of all healthy years lost in the European Union in 2002, and **12.5%** of all healthy years lost in the United States and Canada (Annals of Oncology, 2007).
 - Cancer care cost the European Union **€126 billion** in 2009, with direct healthcare costs accounting for **€51 billion** (40%). The direct healthcare costs per person ranged from €16 in Bulgaria to €184 Luxembourg (Luengo-Fernandez et al., 2013).
 - In a 2014 report, the McKinsey Global Institute concluded that, based on disability-adjusted life years (DALY) data, obesity has roughly the same economic impact (about **\$2 trillion** or **2.8%** of global GDP) as smoking or the combined costs of armed violence, war, and terrorism (McKinsey Global Institute, 2014).
 - According to the WHO, over a period from 2011–2025, the cumulative economic losses due to NCDs under a “business as usual” scenario in low- and middle-income countries could reach **\$7 trillion**, as compared to an annual expenditure of **\$11.2 billion** to implement a set of high-impact interventions (WHO, 2014a).
-



IMPACT CHANNEL 5 FOOD INSECURITY



Food security is an important determinant of individual health, and of public health. On global, regional, national, community, and household levels, food security is achieved when “all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life.”

HOW DO HEALTH IMPACTS OCCUR THROUGH THIS CHANNEL?

Food security is an important determinant of individual health (Mikkonen and Raphael, 2010), and of public health (Neff, 2014). On global, regional, national, community, and household levels, food security is achieved when “all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO, 1996). At the individual level, food insecurity resulting from a lack of access to sufficient, safe, and nutritious food entails a series of direct and debilitating health impacts.

Acute hunger/undernourishment

Inadequate intake of calories and proteins (protein-energy malnutrition/PEM) is the leading cause of death in children in developing countries. Under-nourishment is a contributing factor in 45% of the 16,000 deaths each day of children under the age of five (GLOPAN, 2016). Stunted growth and compromised neurodevelopmental capacity are also common consequences of PEM.

Micronutrient deficiencies (MNDs)

Diets that are insufficient in micronutrients lead to a range of health problems throughout people’s lifespans. MNDs lead to risks of stunting, reduced immune function (and resulting risks of infection), loss of productivity, reduced mental capacity, and chronic disease (Bailey et al., 2015; Schaible and Kaufmann, 2007); they are also a major risk factor in tuberculosis and HIV transmission from mother to child. The most prevalent MNDs globally are iron, iodine, folate, vitamin A, and zinc deficiencies. Deficiencies in these nutrients can lead to conditions such as anemia (iron), blindness (vitamin A),

hypothyroidism and goiter (iodine), neural tube defects (folate), and increased risk of infections (zinc). There are currently 2 billion people globally suffering from MNDs (Knez and Graham, 2013).

Mental health impacts

Long-term health consequences of childhood exposure to hunger include greater risks for conditions such as depression in adolescence and early adulthood (Kirkpatrick et al., 2010; McIntyre et al., 2013). But even without the experience of hunger, studies have shown an association between food insecurity and stress, depression, and anxiety (Weiser et al., 2015), triggered when individuals experience food insecurity: due to uncertainty about their ability (financial or otherwise) to obtain food; by having to reduce the quality, variety, or quantity of the food their families consume; or by experiencing hunger occasionally.

Disease management

Overall, food insecure individuals are likely to have poorer health (Vozoris and Tarasuk, 2003), even when not experiencing the worst consequences of hunger and undernutrition. In a Canadian study of chronic physical and mental health conditions among adults (Tarasuk et al., 2013), experiences with food insecurity were closely associated with stomach or intestinal ulcers, mood/anxiety disorders, migraines, hypertension, heart disease, diabetes, bowel disorders, back problems, arthritis, and asthma. Indeed, if not the cause, food insecurity makes it difficult for individuals to manage existing chronic health problems, such as coronary disease, diabetes, and HIV (Anema et al., 2009; Chan et al., 2015; Weiser et al., 2015).

Who is affected?

The worldwide proportion of adults suffering any degree of undernourishment has declined from 18.6% in 1990–92 to 10.9% in 2014–16 (FAO/IFAD/WFP, 2015). Sixty developing countries met or exceeded their Millennium Development Goal targets of halving, between 1990 and 2015, the proportion of people who suffer from hunger (FAO/IFAD/WFP, 2015). And globally, the prevalence of chronic malnutrition in children has continued to decline, from 40% in 1990 to 24% in 2014 (WHO/UNICEF/WBG, 2016). Still, today, 2 billion people worldwide suffer from micronutrient deficiencies (MND), and nearly 800 million suffer from calorie deficiency (IFPRI, 2016). Children are particularly vulnerable, with over 159 million malnourished children under the age of five in the world (GLOPAN, 2016; IFPRI, 2016). The prevalence of underweight (low weight for age) children in Southern Asia is over 14% (WHO/UNICEF/WBG, 2016). Clearly, progress in addressing food insecurity has been uneven around the world. While the rate of stunting among children has in general been declining by more than 30% since 1990, it has been declining at a slower rate in Africa (by only 17%), where in fact the absolute number of stunted children under five continues to grow (IFPRI, 2016). Indeed, in some African countries (e.g., Nigeria) some evidence suggests a rise in food insecurity since 2009 (Fawole and Özkan, 2017).

ANNUAL COSTS OF HUNGER & FOOD INSECURITY

\$ **67**
BILLION
.....
USA

MALNUTRITION COSTS GLOBALLY

\$ **3.5**
TRILLION

11[%]
OF WORLD
GDP

Box 5

COUNTING THE HUMAN AND ECONOMIC COSTS OF FOOD INSECURITY: SELECT ESTIMATES

- **Malnutrition costs \$3.5 trillion globally, which is 11% of world GDP.** This encompasses wasting (acute malnutrition) and stunting (chronic malnutrition), as well as MNDs (IFPRI, 2016).
- The “Cost of Hunger in Africa” study found that **child undernutrition in four African countries incurred economic losses equivalent to between 1.9% (Egypt) and 16.5% (Ethiopia) of GDP** (African Union Commission et al., 2014).
- One conservative estimate of the health costs of **hunger and food insecurity in the United States**, excluding missed workdays and nonmedical costs, still amounted to **\$67 billion USD** per year in 2005 dollars (Brown et al., 2007).
- A recent Canadian study estimated that the **total annual health costs** for adults living in severely food insecure households is **121% higher** than for those in food secure households (Tarasuk et al., 2015).
- **MNDs** are estimated to cost developing countries between **1% and 5% of GDP** annually (Stein and Qaim, 2007).
- **Iron deficiencies**, the most common type of MND, can result in a **median productivity loss of about \$4 per capita, or 0.9% of GDP** in developing countries, with even higher costs in industrialized countries due to higher wages (and despite lower prevalence) (Darnton-Hill et al., 2005). South Asia suffers from the highest prevalence of **anemia**, which costs **\$5 billion** to the region annually.

HOW MUCH DO WE KNOW ABOUT THESE IMPACTS AND HOW WELL ARE THESE FOOD-HEALTH LINKAGES UNDERSTOOD?

Generally, the effects of undernourishment and malnutrition on human health are well known, and there are very few controversies about them. But there is often much debate about the incidence of food insecurity and its underlying causes. Food security has evolved to be a multidimensional concept, implying conditions not only at the individual level, but also at the household, community, and country levels. It refers to the availability of food, but also (and often primarily) to people’s access to it, and how food is used. Thus, measurements of food insecurity have varied according to which dimension or feature is emphasized (Barrett, 2010), and they are very context-dependent. It is not uncommon to find widely different estimations of food insecurity for even the same country (Fawole and Özkan, 2017). The Food Insecurity Experience Scale (FIES), a validated tool developed under the FAO’s *Voices of the Hungry* project, has paved the way for some international comparisons of the incidence of food insecurity experienced by people around the world (FAO, 2016). Indeed, the 2014 survey confirmed the systematic nature of food insecurity, finding incidence of some degree of food insecurity among adults in Belgium (7.8%), Canada

(8.0%), and Italy (8.2%) — only slightly below Brazilian rates (8.3%). FIES results also indicate that over 10% of the adult population in the United Kingdom and in the United States experience some degree of food insecurity.

At the individual level, an existing disease burden has been identified as a risk factor for food insecurity (Castleman & Bergeron, 2015). Disease can impair the nutritional status of individuals, reduce household income due to loss of working days, and compete for the scarce resources of the poor through the cost of healthcare. Other causes of food insecurity have been identified in the interaction among socio-economic, environmental, and political factors embedded in, and impacting, food systems. Among the underlying (but interacting) causes of food insecurity, the most cited by international organizations and researchers (see for example Caritas Australia, 2015; Castleman et al., 2015; FAO, 2015; Godfray et al., 2010; Harvest Help, 2012) are the following:

- **Poverty:** The most important immediate cause of food insecurity everywhere is people's lack of access to adequate, safe, and nutritious food; the preeminent reason for this lack of access is insufficient income to participate in markets where food is sold. Poverty also threatens food security through its association with poor sanitation, inadequate healthcare, and poor childcare and feeding practices at the household level (see Section 3).
- **Food price shocks:** Because much of the food people need is purchased, sudden price hikes can significantly impact food security. These can come from local or internal conditions in a country (e.g., due to a major drought), or price hikes can be instigated by international conditions (such as those affecting global grain prices in 2007–2008), given the increasing globalization of food markets.
- **Natural disasters and climate change:** While droughts and other extreme weather events (floods, typhoons, and cyclones) can be seen as local conditions leading to poor harvests, food scarcity, and higher food prices, climate change (a global phenomenon) is playing an increasing role in driving these events. Still, the impact of climate change on food security can vary depending on different geographical characteristics and different regions' capability for adaptation.
- **Agricultural problems:** A number of agricultural problems, such as pests and livestock diseases, can impact the capacity of a region to produce food, leading to scarcity and food insecurity. Gaps in agricultural knowledge and poor practices can lead to low productivity. Environmental degradation of agricultural resources (water quality and availability, soil health) is a major preoccupation in many regions. Of increasing concern is a decline in available farming land due to a range

of reasons, from soil erosion, to urbanization, to “land grabbing” by international investors.

- **Population growth:** The challenge of feeding an increasing world population with scarce resources has been highlighted for over 200 years. More recently, while the rate of population growth has declined, renewed concerns have been expressed due to deteriorating environmental resources. Food security concerns have been particularly intense for regions experiencing both rapid population growth and a significant decline in their resources for food production.
- **Poor governance and policies:** Many studies, in different parts of the world, at different times, have pointed out government corruption (such as in deviating food aid during emergency situations) and political conflicts as potential drivers of food insecurity. Food insecurity can also emerge, as suggested in different studies, as the unintended consequence of national policies (e.g., land reforms in Zimbabwe), or international trade agreements, which disadvantage small-scale farmers. Insufficient public investment, particularly in agriculture and in supporting women farmers, has also been identified as a major contributor to food insecurity.

Much controversy on addressing food insecurity is based on which causes are prioritized, and which measurements are used. In selecting some causes over others, or some measurements over others, some features of food insecurity end up being neglected. Such choices have significant consequences, as they influence what interventions or solutions are proposed. But as the discussion here (and for other health impact channels) suggests, a complex web of causality and diverse interactions with food systems should serve as a warning against analytical simplifications and silver bullet solutions.



SECTION 3

WHAT HOLDS BACK OUR UNDERSTANDING OF HEALTH IMPACTS AND OUR ABILITY TO ADDRESS THEM

KEY CHALLENGES

The preceding analysis has shown that food systems affect health through multiple, interconnected pathways, generating major human and economic costs. The health impacts generated by food systems are severe and widespread, and are being increasingly documented. These impacts are not limited to isolated pockets of unregulated production in specific locations, or to those excluded from the benefits of modern agriculture and global commodity supply chains. Many of the health risks profiled in Section 2 trace back to some of the core industrial food and farming practices, e.g., chemical-intensive agriculture; intensive livestock production; the mass production and mass marketing of ultra-processed foods; and, the development of long global commodity supply chains with dispersed accountability and often dangerous and deregulated conditions. The scope, severity, and cost of these impacts suggests that historical progress in tackling problems like hunger, foodborne illness, and workplace injury may be slowing or even unravelling, while a range of additional disease, contamination, and diet-related risks are emerging fast. The industrial food and farming model does not bear the entire burden for these problems, but has clearly failed to provide a recipe for addressing these problems individually or collectively. An urgent case for reforming food and farming systems — and rethinking the industrial model in particular — can therefore be made on the grounds of protecting human health. The five channels (see page 12) help to understand how and where these risks accumulate, and to identify the

gaps and complexities in the respective scientific debates. Each channel thus becomes a focal point for the action that is required to mitigate the impacts of, or find alternatives to, the prevailing industrial food and farming model.

The analysis also sheds light on the systemic nature of these health risks. The health impacts of food systems are interconnected, self-reinforcing, and complex. Food systems impacts are caused by many agents, and interact with factors like climate change, unsanitary conditions, and poverty — which are themselves shaped by food and farming systems. Several of these impacts reinforce one another, within and across the five channels. For example: the stress generated by high-pressure work environments in industrialized food processing plants is itself a key factor in increasing the risks of frequent physical injury (Lloyd and James, 2008); undernutrition and pre-existing disease burdens make people more sensitive to the impacts of environmental change and contamination (Whitmee et al., 2015), and at further risk of food insecurity; and, livestock disease risks, e.g., in confined CAFO-style environments, encourage the extensive use of antibiotics, which in turn allows antimicrobial resistance (AMR) to spread. In other cases, risks are hard to trace to specific points in food systems, and tend to accrue across a range of food systems activities and over long periods of time. For example, zoonotic pathogens originating in livestock can spread through multiple pathways within and around food systems, thereby multiplying the risks and making it difficult to identify the source of outbreaks; antimicrobial resistance, meanwhile, is perpetuated by a complex interplay of ecological and genetic factors, spreading through multiple channels, multiplying the risks through contact between bacteria (forming “multidrug resistant” bacteria), and accruing through the combined animal and human uses of the same antibiotics (Marshall and Levy, 2011; You et al., 2012). Chronic exposure to Endocrine Disrupting Chemicals (EDCs) is particularly hard to trace to specific sources or even to specific chemicals. Furthermore, food system practices do not act alone in driving these impacts; factors such as climate change and poverty play an important role in what emerges to be a complex causal web. As will be discussed below, this complexity is real and challenging, but should not be an excuse for inaction.

The analysis below places these impacts in the context of a broader food–health nexus, i.e., the web of interactions, imperatives and understandings at the intersection of food and health. Our attention is focused on the interface of science, policy, practice, and public awareness, where understandings are forged, narratives are reinforced, imperatives are cemented, and modes of thinking and acting are embedded. We ask how the inherently complex, self-reinforcing, and systemic nature of health risks plays out in the context of highly embedded imperatives and highly unequal power relations in food systems. In other words, are the connections made visible between the impacts, between different groups of people, between different parts of food systems, and between food systems and their broader social and ecological

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context, or are they lost from view and reduced to narrowly framed solutions? Does the interconnected nature of these impacts help to make the case for systemic reform, or does it simply lock these impacts into the fabric of food systems? We identify seven key challenges that must be overcome in order to pave the way for comprehensive understanding and appropriate action to address the problems identified in Section 2. In brief, these challenges concern our ability to see the full picture of food system impacts (Challenges 1–2), understand the connections between impacts and across food systems (Challenges 3–6), and communicate them at the science-policy interface (Challenge 7).

Seven key challenges affect our ability to see the full picture of food system impacts, understand the connections between impacts and across food systems, and communicate them at the science-policy interface.

**CHALLENGE 1:
OVERCOMING BLIND SPOTS IN THE EVIDENCE BASE
POPULATIONS WITHOUT POWER, PROBLEMS WITHOUT VISIBILITY**

As described in Impact Channel 1 (Occupational Hazards), the precarious working conditions across global food systems create a situation in which those exposed to the greatest health risks are not seen or heard. In particular, the insecure status of hired and migrant labourers, and high turnover among labourers, works against the reporting of abuses and impacts. The economic imperatives running up and down the food chain perpetuate these insecure conditions and dissipate responsibility. The “buyer-driven” chains that characterize sectors such as horticulture allow companies sourcing foods/ingredients to work in a flexible way with a range of potential suppliers, who are themselves responsible for contracting labour, in a context of high competition for these retail contracts and thus severe cost pressures (Barrientos et al., 2016; Dolan, 2004; Gereffi, 2001). These arrangements make it less likely for abuses to be reported to the direct employer, let alone for these complaints to be taken further up the chain.

Women are disproportionately affected by many of the health impacts described in Section 2. This reflects the gender division of labour in agriculture. For example, women are more exposed to water contamination since they do much of the rice transplanting work. Also, there is an increasing feminization of agriculture around the world. For instance, in 2008 in Asia, 43% of all farm workers were female (and 48% in China); in Africa, women represent almost 50% of agricultural workers (Agarwal, 2014). The relatively low power and visibility of women in many societies is therefore likely to translate into lower visibility of the health impacts faced by this increasingly key section of the food and farming workforce.

Geographic discrepancies in terms of power, visibility, and exposure to risks are also embedded in global food systems. Many of the most severe health

impacts (e.g., pesticide poisoning, hunger) affect the Global South disproportionately. For all channels of impact, data availability is highly variable across different world regions, with information tending to be less complete for countries in the Global South. Occupational risks to farmers and farm-workers in developing countries are particularly under-reported, e.g., due to highly incomplete records on pesticide usage and impacts. Documentation of the scope and severity of these problems is also undermined by lack of reliable census/population data, making it difficult to estimate the percentage of a given population group, e.g., farmers, suffering a given impact. Gaps affecting the Global South are particularly consequential, given how many of the world's farmers, farm labourers, and food workers are in the Global South: some 60% of employment in Sub-Saharan Africa is estimated to be in agriculture (FAO et al., 2015). Reporting discrepancies are not limited to occupational hazards. The official reporting of foodborne illnesses and hospitalizations is low around the world, but particularly in developing nations where the burden is likely to be highest (WHO, 2015a).

These blind spots and hidden impacts make it less likely for problems to be prioritized politically, allowing health risks to continue accruing to marginalized populations. Even within wealthy countries, a vicious cycle can be witnessed whereby health conditions of marginalized populations are often poorly documented, researched, and addressed, reinforcing the social-health inequalities between different groups in society. For example, the health status of indigenous groups in North America has been frequently overlooked by mainstream research (see, for example, Eldridge et al., 2015; Wilson and Young, 2008). Furthermore, health-related inequalities may be self-reinforcing over time as a result of social (im)mobility. Historically, poorer populations have tended to be concentrated in the more polluted areas of cities. The industrial revolution saw wealthier populations move upwind, meaning that the East End of cities like Manchester and London — where factory fumes tended to blow and factory wastes were disposed of — became increasingly working class, with these patterns persisting even after a crackdown on air pollution (Heblich et al., 2016). This geographic clustering of poverty and poor health means that large swathes of the population — including those with the greatest power and influence — are physically removed from some of the gravest health problems.

The full extent of the health burden is also obscured by deficiencies in health-care provisions in poorer countries. Cardiovascular diseases are the leading cause of death worldwide, but sudden deaths from heart attacks are more common in developing countries. In these cases, devastating impacts occur “with no lingering burden on the health system” (Chan, 2016). Similarly for cancers, expensive treatments are not available or accessible to most people around the world. As a result, the current costs associated with these diseases in developing countries are much lower than they would be if high-quality healthcare were more evenly available around the world. These discrepancies

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may allow the focus to remain on developed countries where the major costs are amassed and counted — thus potentially downplaying the global and systematic nature of the obesity epidemic, and the “double burden” of undernutrition and overweight increasingly experienced by low-income and middle-income countries.

Systematic blind spots therefore undermine our ability to get a full picture of the impacts in food systems. Much of the available evidence — including the majority of evidence cited in this report — relies on data gathered in North America and Europe, and published in primarily English-language journals situated in those regions. This risks downplaying the extent of a specific health impact in the Global South relative to the Global North, and also allows the framing of the key health impacts in global food systems to be disproportionately based on understandings emerging from the Global North.

CHALLENGE 2: RECLAIMING RESEARCH FOR THE PUBLIC GOOD

How research is structured and financed, how problems are framed and research priorities are set, how data is gathered and to whom it is accessible has a major impact on our understanding of the health impacts of food systems. Challenges in this regard emerge across the impact channels. In many countries and many sectors, the commitment of governments to fund research as a public good, or even to make data and research results available as a public good, has been increasingly compromised (see, for example, New, 2017). In the past few years, many governments have reduced their support to all types of researchers, international research organizations (Dalrymple, 2008), and even to public national surveys. Public sector agricultural research has been dramatically scaled back over recent decades, with government cuts straining higher education and agricultural research budgets (King et al., 2012; Muscio et al., 2013).

Public sector funding cuts have generated a void that is increasingly being filled by private interests. This creates several problems. First, some issues of high public interest may not attract funding from private investors. For example, the gradual privatization of research funding has come alongside an increasing focus on those commodities for which there is a large enough market to secure a significant return on investment (Piesse and Thirtle, 2010). In this context, minor species and traditional crop varieties have been neglected (Rahman, 2009), despite their nutritional benefits. Meanwhile, the need for analysis of system-wide interactions and solutions — so relevant for addressing health risks in food systems — is falling through the cracks. This is

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reflected in the lack of interaction between different disciplines in many agricultural colleges (O'Brien et al., 2013), the lack of attention to the complex interactions between the natural environment and human society that underpin food systems (Francis et al., 2003), and the high proportion of doctoral and post-doctoral research topics in highly specialized fields of biotechnology as compared to research on agroecology (Francis, 2004).

Second, these trends have implications for the validity of the research that does emerge. While private funding can and often has produced good research and evidence, industry-funded research has in a variety of contexts and sectors been found to disproportionately favour outcomes aligned with industry interests (Bhandari et al., 2004; Lexchin et al., 2003; Perlis et al., 2005; Scollo et al., 2003). This can occur through conscious or unconscious influence on the definition of research questions (Bero, 2005; Lesser et al., 2007; Scollo et al., 2003), the experimental design (Djulbegovic et al., 2000; Lexchin et al., 2003), the implementation of statistical analyses (Lesser et al., 2007), the interpretation of statistical results (Alasbali et al., 2009; Golder and Loke, 2008), the extent or quality of peer review (Barnes and Bero, 1996; Scollo et al., 2003), and industry-related delays, suppression, or dissuasion regarding the publication of specific results (Bero, 2005; Lexchin et al., 2003; Okike et al., 2008). Industry influence over the framing of the research agenda and the terms of the broader scientific debate has also been identified through a range of additional practices: employing individual researchers as consultants or inviting them to sit on company boards in order to signal objectivity and legitimacy; funding professional and academic associations; publicly critiquing established but “inconvenient” evidence and sowing doubt about its validity, often through the use of front groups (see Challenge 7: Communicating complexity at the science-policy interface); and, using corporate social responsibility programs as marketing campaigns (e.g., to shift the focus from obesogenic diets onto the importance of active lifestyles by sponsoring sporting events). These practices have been increasingly identified in relation to nutrition science (see Impact Channel 4: Unhealthy Dietary Patterns) with major implications for shaping understandings. In particular, the decades-long attempts to shift attention from sugars onto fats is likely to have lasting implications in terms of creating general confusion around the role of different dietary components.

The increasingly prominent role of private actors, and the declining role of public research, also raises questions about data availability and access. Access to data on farm-level trends, environmental conditions, and disease incidence is essential in order to study, record, build understanding of, and develop appropriate policies to address various health impacts in food systems. Privately funded research in these areas may be deficient, or the data and results generated from such projects may not be divulged, raising major issues of transparency and accountability. Data withholding and access problems affect all of the impact channels. For example, lack of data collection by industry, or lack of access

to that data, has been identified as a major obstacle to identifying the health impacts of CAFOs on surrounding populations (National Research Council, 2015). Risk assessments for new technologies and chemicals (such as EDCs) also tend to rely on data generated and controlled by major agri-business firms, while information around biotech crops is notoriously difficult to access. In 2009, 26 university crop scientists wrote to the US Environmental Protection Agency complaining that patents on engineered genes were preventing public sector scientists from researching the potential impacts of GM crops (Pollack, 2009). While most biotech companies now have agreements with universities on use of their patented technologies for research, scientists must still negotiate permission to conduct these studies from the companies themselves (Haspel, 2014; Stutz, 2010). Risk assessments for novel food additives are particularly reliant on industry data and private sector governance. As seen in Section 2, under US law, it is the responsibility of manufacturers to assess whether new substances are generally regarded as safe (GRAS) by scientific experts, with notification made voluntary and with little scope for public scrutiny.

Recent advances in “Big Data” could pave the way for major improvements in monitoring and mitigating food systems impacts, e.g., by deploying farm-level soil data to enable more targeted use of chemical inputs. However, current trends raise concerns about how that data will be used and to whom it will be available; vertical integration is continuing apace across the agri-food sector, with a handful of firms gaining an increasingly dominant position, and company information becoming ever-more opaque (IPES-Food, forthcoming).

The challenge, therefore, is not simply to curb the production of research and data by private actors. The interaction between researchers and industry funding is highly complex, since in many instances, and particularly given public funding shortfalls, researchers are required to attract private funding sources and voluntarily approach industry members in search of grants. Such situations require at a minimum a careful analysis of potential conflicts of interest. Nor does public research always reflect public interests. In a context of increasing privatization, public-sector research has tended to echo the emphasis of private research agendas, e.g., mirroring the focus on increasing productivity for a small number of tradable crops via technological innovation (Jacobsen et al., 2013). Moreover, without major reinvestment in public data gathering, private firms will continue to be best-placed to conduct monitoring of risks and outcomes across food systems. Research priorities, structures, and capacities therefore need to be fundamentally realigned with principles of the public interest and public good. These principles, in turn, may need to be redefined through democratic processes and brought into line with the nature of the challenges food systems now face (i.e., cross-cutting sustainability challenges and systemic risks). The challenge, therefore, cannot be addressed within the scientific domain alone, and requires new ways of addressing food system risks at the interface of science, policy, and public debate (see Section 4).

Research priorities, structures, and capacities need to be fundamentally realigned with principles of the public interest and public good. These principles, in turn, may need to be redefined in democratic processes and brought into line with the nature of the challenges food systems now face.

CHALLENGE 3: BRIDGING THE DIVIDE BETWEEN FOOD AND AGRICULTURE

The blind spots in the evidence base, and particularly the risks accruing to food and farmworkers around the world, are compounded by a broader disconnection of the general public from the process of food production. This disconnection may be observed on three levels: physical (between high-population urban zones and the rural zones where food is produced); economic (more intermediaries between consumers and farmers, with a greater share of value moving up the supply chain at the expense of farmers); and, cognitive (decreasing knowledge of how food is produced and processed) (Bricas et al., 2013). These trends are particularly relevant in wealthy countries, where agriculture now makes up only a fraction of employment, e.g., around 1.5% in the United States (Bureau of Labor Statistics, 2013), and is often undertaken by seasonal migrants whose contact with the general population may be limited.

As a result, the fact that food choices have implications for farming systems (and the health of those working within them) has become less obvious and, as a consequence, may be considered less important in the hierarchy of daily concerns. Even when farm issues are reported and brought to broader public attention, the links to the foods — and the brands — people buy on a daily basis are not always clear (Cook, 2010). Given the dispersed accountability and opaque nature of long global value chains (see Challenge 1), the connections to agricultural workers in distant countries are even less intuitive. The global nature of food systems leaves many people one step removed from the realities of food production. For example, while European consumers may see animal agriculture in their own regions, as much as 70% of the protein-rich animal feed used in EU livestock production is imported (Schreuder and De Visser, 2014), in particular from South American countries where deforestation, evictions, pesticide poisoning, and rights abuses have been alleged in intensive export cropping zones (Ezquerro-Cañete, 2016; Mekonnen et al., 2015).

The physical and cultural disconnect from agriculture may also undermine awareness of impacts to which people are themselves exposed, especially impacts transiting through environmental contamination. Chronic exposure-based impacts are particularly hard to trace to specific sources at specific points in time, but are closely associated with industrial agriculture (see Section 2). Agricultural contamination of air and water often occurs significantly upstream or upwind of where health impacts actually manifest themselves, e.g., in urban settings. Impacts of this type may be more readily associated with contributing factors in closer proximity (e.g., transport pollution, factory waste), particularly in the absence of connections to and knowledge of upstream agricultural realities.

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This does not mean that the general public is indifferent to the plight of food and farmworkers or the ways in which food is produced. Recent events suggest that targeted campaigns to bring abuses to light can garner public support, visibility, and political traction. For example, the withdrawal of the fumigant methyl iodide from the US market came on the back of vocal campaigns in which a broad spectrum of citizens mobilized in regard to risks almost exclusively accruing to farmworkers in the strawberry sector (United Farm Workers, 2017). Meanwhile, recent campaigns for a \$15 “living wage” for fast-food workers in the United States have gained major visibility and widespread support (Davidson, 2015). And in some cases people are looking upstream and reconnecting their own health with agricultural systems. While dismissed by the federal district courts, Des Moines’ lawsuit against upstream agricultural zones in Iowa may have symbolic importance in reconnecting people with agricultural realities and positioning them as stakeholders in the management of farming systems. The lawsuit sought to redefine the nitrate contamination of the city’s water supplies as “point source” pollution and called for redress under legislation designed to protect consumers — the Clean Water Act (Eller, 2017).

These developments are promising, suggesting a growing solidarity with those producing our food, a growing willingness to challenge harmful modes of production and become active stakeholders in those debates, and a willingness to make the way our food is produced a matter of public interest and public health. A critical mass of public awareness is required to force issues up the political agenda, particularly when those affected have the least power and visibility (see Challenge 1), and in some cases this has been achieved. However, public awareness of the problems in food systems — and particularly those affecting food and farmworkers in distant locations — remains sporadic. The challenge may be to build understanding that the poor conditions that periodically come to light are the norm, not the exception, for many around the world. Moreover, these conditions are sustained by the personal food choices we make and the policies decided (at least nominally) in our name. Ultimately, a pool of cheap and insecure labour, dangerous conditions and systematic stresses for farmers and foodworkers are what sustains the low-cost commodity production at the base of global food systems. Keeping the bulk of these problems out of the public eye and off the record-books — and ensuring that these problems, when they emerge, are perceived as anecdotal rather than systemic — is what maintains the fragile contract between consumers who want affordable and abundant (but not exploitation-based) food, a system that provides it, and the governments who shape the underlying priorities (e.g., through agricultural, food, and trade policies favouring cheap commodity production). Reconnecting people with the realities of the food they eat — and bringing the true cost of the cheap food model to light — is therefore a major leverage point for unlocking the food-health nexus.

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CHALLENGE 4: BROADENING THE FRAME OF THE NUTRITION PROBLEM

Debates around diets and nutrition — both under- and over-nutrition — are particularly vulnerable to framings that obscure key connections and undermine the basis for comprehensive understanding and systemic action to address health risks in food systems.

Food security is often framed in terms of “feeding the world,” i.e., delivering sufficient net calories at the global level. Narratives and solutions put forward by agribusiness firms, international agencies, governments, and a variety of other actors often emphasise this aspect of the challenge. Approaches of this type tend to minimize the questions of how, where, and by whom additional food is grown, and the questions of distribution, access, and power on which hunger is often contingent (see IPES-Food, 2016). This has often remained the case even when the focus on productivity has been broadened to take in nutritional concerns, e.g., “food and nutrition security.”

In many development schemes and research programs, the focus has been placed on single nutrients through supplementation, fortification, and biofortification, with little emphasis on durably improving people’s access to diverse diets (Frison et al., 2006; Burchi et al., 2011). A focus on single nutrients also remains pervasive in discussions around dietary guidelines. These approaches have been criticized for promoting “nutritionism” — the reduction of food’s nutritional value to its individual nutrients — at the expense of broader understandings and more systemic solutions. For some, nutrient-focussed guidelines are a legacy of a time when food insecurity was the primary diet-related issue, and risk promoting the (excess) consumption of foods that nominally meet nutrient cut-offs, regardless of their broader implications for health and how they fit into a healthy dietary pattern (Jessri and L’Abbe, 2015; Mozaffarian and Ludwig, 2010). A focus on single nutrients also paves the way for multinational food companies to use “nutritional positioning” to bolster their power and influence (Clapp and Scrinis, 2017, p. 578).

In response to such criticisms, new approaches to dietary guidelines are increasingly food-focused, emphasizing greater consumption of foods that most contribute to healthy diets, as well as the avoidance of those foods whose consumption is most likely to lead to unhealthy diets (e.g., Brazil, 2014). However, the legacy of “nutritionism” lives on and is proving hard to shift politically. Even when the focus is on foods and food groups, misunderstandings around nutrients can be propagated. For example, the USDA’s decision to classify dairy as a “food group” (e.g., for the purposes of its My Plate guide) has been criticized for promoting a view that dairy products are needed to

obtain calcium and to underpin a healthy diet, despite calcium being present in a range of other foods (Hamilton, 2016; Harvard School of Public Health, 2012), and despite ongoing concerns about consumption of saturated fats (see Impact Channel 4: Unhealthy Dietary Patterns). Indeed, a major conflict of interests has been alleged, given that the USDA is also responsible for promoting dairy commodities as part of its core business.

A more nuanced and holistic debate about the nutritional outcomes of food systems can be observed when discussion is framed around “nutrition-sensitive agriculture” (Jaenicke and Virchow, 2013; Maluf et al., 2015; Ruel and Alderman, 2013; Wesley, 2016). This concept expands the scope well beyond calories and specific micronutrients, considering the nutritional implications of food production models and their environmental interactions (e.g., via soil health), as well as the implications of food processing and utilization for nutritional value. In other words, this approach questions the assumption that nutrition can be improved without explicit consideration of food production, distribution, processing, policy, and programming. However, not all definitions — and not all interventions — reflect this holistic view. The US Agency for International Development (USAID, 2015) has defined nutrition-sensitive agriculture as “agriculture investments made with the intention of also improving nutrition.” In this context, technological approaches such as seed biofortification can also be framed as “nutrition-sensitive agriculture,” and the focus on delivering nutrition through the food system is at risk of dilution.

A tension can also be observed between attempts to frame diets as a function of broader food environments and persistent narratives suggesting that diet-related health is simply a question of personal responsibility. As described in Impact Channel 4, framing health impacts in relation to the food environment changes their complexion considerably, shifting the attention from individuals onto the socio-economic factors in which people’s choices are embedded. However, reviews of public and media discussion around obesity have found persistent framing around individual responsibility, with environmental and structural drivers less frequently mentioned (De Brún et al., 2015; Saguy and Almeling, 2008). A return to individual responsibility has also been identified in the prevailing advice to consume various items “in moderation.” While advice of this nature may be fundamentally sound, it has been criticized for downplaying the factors shaping people’s choices, as well as implying that all foods can be part of a healthy diet (Nestle, 2003; Heiss, 2013; Simon, 2006).

As described in Section 2, obesity and diet-related NCDs are multifactorial, while the specific contribution of different dietary components can rarely be identified with certainty. The underlying causes of hunger and MND are also wide-ranging. This brings a degree of inherent complexity, and requires attention to socio-economic and political factors, and to the power relations running

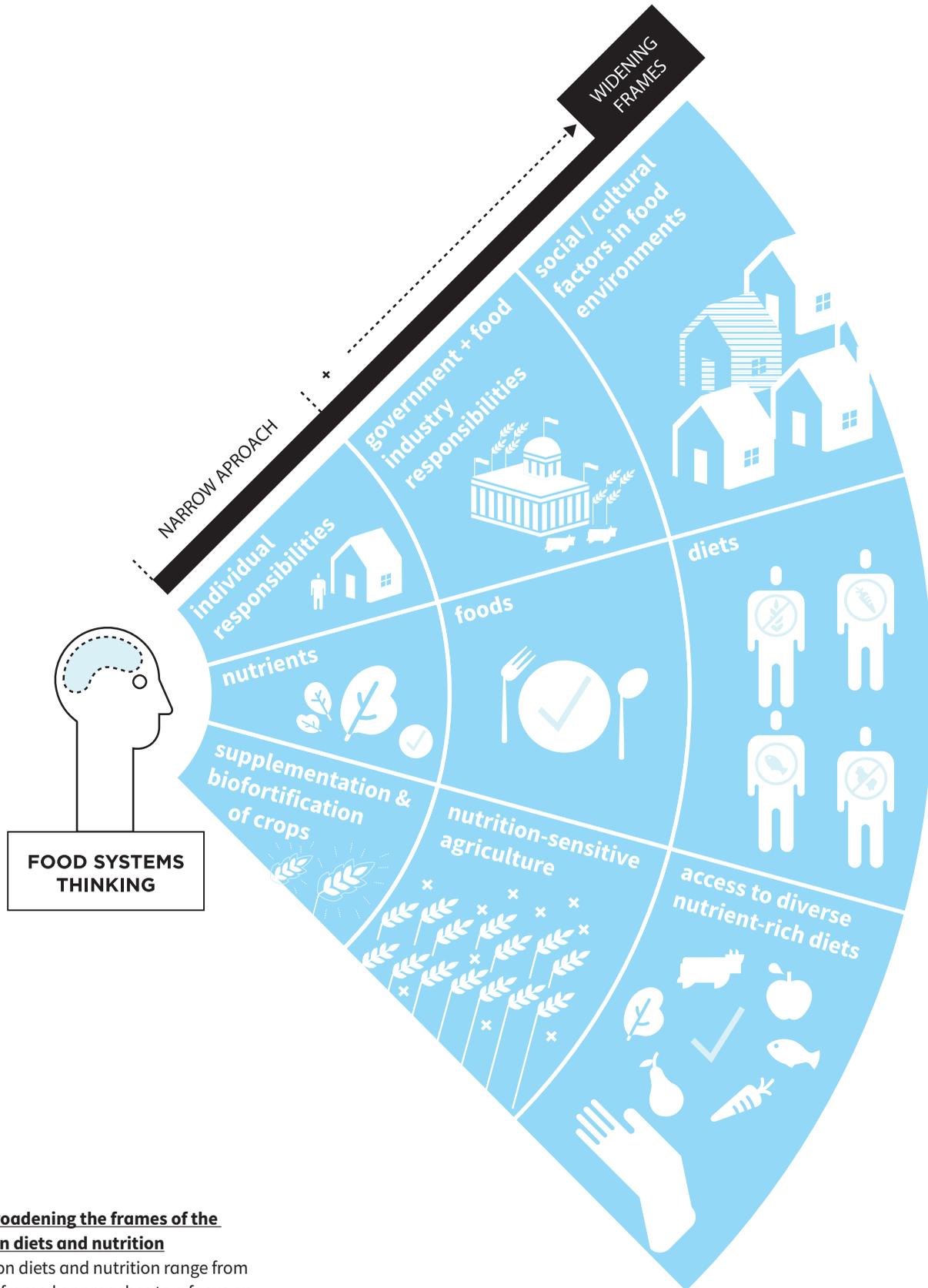


Fig. 5: Broadening the frames of the debate on diets and nutrition

Debates on diets and nutrition range from narrowly framed approaches to a focus on the broader socio-economic conditions for health and sufficient diets.

across food systems and determining people's access to food. However, prevailing narratives and imperatives tend to disconnect different pieces of the puzzle, promoting incomplete understandings and piecemeal actions, and leaving the root causes of unhealthy and insufficient diets unaddressed.

CHALLENGE 5:
ADDRESSING THE FOOD-HEALTH-CLIMATE NEXUS
RECONNECTING HEALTH RISKS TO ECOLOGICAL DRIVERS

As indicated throughout Section 2, many of the health risks in food systems are deeply intertwined with ecological change and degradation. However, the full extent of these interactions — and their cyclical nature — is often overlooked. In particular, food systems are a major driver of climate change, which in turn exacerbates a series of health risks associated with food systems. While estimates differ, food systems may account for as much as 30% of all human-caused GHG emissions (Niles et al., 2017). Climate change, in turn, stands to aggravate a series of health impacts across the channels. For example, the changing climate may bring novel vectors into newly temperate climates, driving alterations in the incidence and distribution of pests, parasites, and microbes, or create temperature-related changes in contamination levels (Newell et al., 2010; Watts et al., 2015); for example, people may also be exposed to a greater accumulation of mercury in seafood as a result of elevated sea temperatures (Ziska et al., 2016). New food safety risks could also emerge as a result of increasing floods and droughts (WFP, 2015). Meanwhile, climate change is likely to provoke crop losses due to changing frequency and severity of floods and droughts, and even to decrease the nutritional value of important food crops, such as wheat and rice, as atmospheric carbon dioxide reduces protein and essential mineral concentrations in plant species (Niles et al., 2017; Watts et al., 2015; Ziska et al., 2016). Through changes in rainfall and temperature-driven shifts in plant biomass, climate change is also expected to affect the extent, frequency, and magnitude of soil erosion (Whitmee et al., 2015), with major knock-on effects for health (e.g., increased nitrogen leaching into water, threats to food production and food security). Climate change is also likely to increase the risks of natural disasters (e.g., landslides, tsunamis) with the potential to exacerbate food-related health impacts, particularly food insecurity (Watts et al., 2015).

Food systems are a major driver of climate change, which in turn exacerbates a series of food-related health impacts.

Food systems also contribute to broader environmental and land use changes in ways that exacerbate specific health risks. As much as half of the emerging zoonotic infection events from 1940–2005 have been attributed to changes in land use, agricultural practices, and food production (Whitmee et al., 2015). Given that agricultural expansion is so often a driver of land use change,

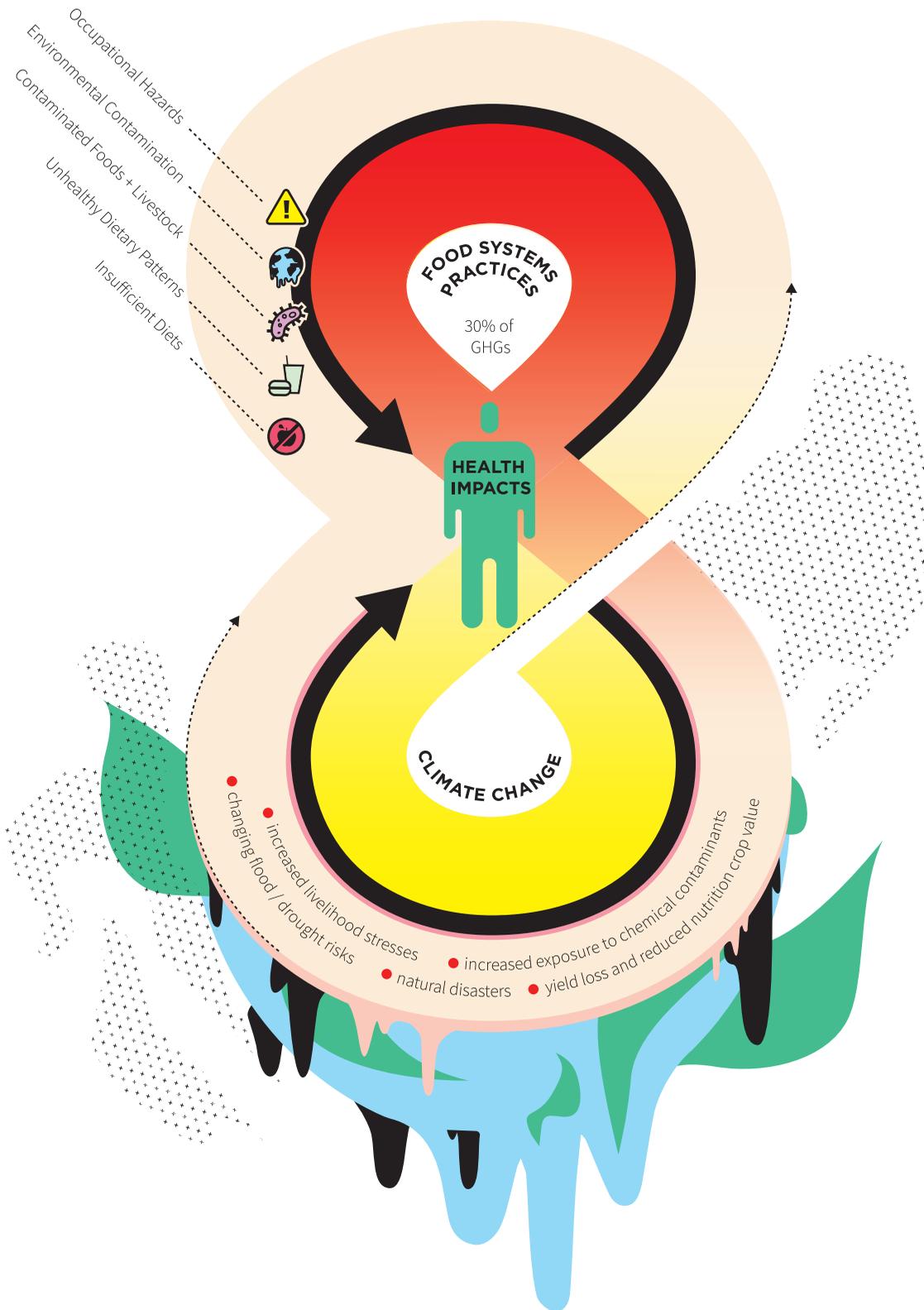


Fig. 6: The Food-Health-Climate nexus
Food systems are a major driver of climate change. In turn, climate change exacerbates a range of health risks associated with food systems.

food systems contribute both directly and indirectly to these impacts. Climate change is likely to be a key driver of these land use shifts (e.g., due to loss of fertility in existing production zones). These impacts are therefore extremely wide-ranging, and highly significant. According to the EPA, “overall, climate change could make it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as we have done in the past.”¹²

It is also important to think beyond health impacts per se and to consider the broader ecological basis for health. The practices associated with industrial agriculture (e.g., chemical-intensive agriculture) are disrupting ecosystems in fundamental ways, and undermining their capacity to provide essential environmental or ecosystem services such as controlling soil erosion, storing carbon, purifying and providing water, maintaining essential biodiversity and associated services (e.g., regulating diseases), and improving air quality (see, for example, Millennium Ecosystem Assessment, 2005; IPES-Food, 2016). All of these services, provided by nature, are under severe threat, with far-reaching implications for human health. For example, with some 35% of global food production dependent on pollination, the loss of pollinators — closely associated with pesticide use — could fundamentally undermine future food production (WHO & Secretariat of the Convention on Biological Diversity, 2015; Whitmee et al., 2015). The general disruption of marine ecosystems is also occurring at a rapid rate, threatening fish populations and thus a key source of protein for many people.

Health risks in food systems are therefore deeply connected to environmental risks, and not only those health risks transiting directly through contamination of water, soil, and air (i.e., Impact Channel 2: Environmental Contamination). Steps to address the environmental impacts of agriculture (including climate mitigation and adaptation measures) are therefore also steps to address the human health impacts of agriculture — and are doubly urgent. Action to date has tended to focus on mitigating specific environmental outcomes of agriculture (e.g., restricting the use of specific pesticides with proven harmful impacts on pollinators) without considering a more fundamental redesign, and without addressing the central role of industrial food and farming systems in driving environmental degradation and disrupting ecosystems (for further discussion, see IPES-Food, 2016).

The broader ecological landscape in which health risks are embedded has also been overlooked in discussion of disease and contamination risks. For example, discussion around zoonotic infections and foodborne disease risks is often focused around increasing “biosecurity” and “biocontainment” in industrial livestock production facilities (or CAFOs). However, this only addresses one part of the problem. Zoonotic disease risks emerge at the intersection of animal, human, and ecosystem health, and respond to processes of globalization, climate change, land use change, and urbanization (Cunningham et al., 2017; Whitmee et al., 2015). The risks cannot be addressed within a specific

The practices associated with industrial agriculture are disrupting ecosystems in fundamental ways, and undermining their capacity to provide essential ecosystem services such as controlling soil erosion, storing carbon, purifying and providing water, maintaining essential biodiversity and associated services, and improving air quality.

CAFO; even the most “biosecure” operation faces a series of potential disease transmission pathways, such as ventilation systems (often required due to the confinement of large herds), insect carriers, or production waste, as well as the underlying problem of increased disease susceptibility of animals in these conditions (see Impact Channel 2) (Graham et al., 2008; Leibler et al., 2009). Moreover, industrial livestock production and its protein feed requirements is itself a major driver of climate change and land use change, which in turn exacerbate infectious disease risks. Key outbreaks of zoonotic disease affecting human populations, e.g., avian flu in Southeast Asia, have multiplied in industrial holdings, although responses have tended to focus on “backyard” operations (and their greater exposure to wildlife) as weak links in the chain, and have framed biosecure industrial holdings as the solution (Graham et al., 2008).

Given the extent of the problems described above, a deeper rethink of the ecological basis for food production and for human health is required. This not only entails consideration of different management practices (particularly for livestock), but also of fundamentally different paradigms based on reintegrating agriculture with the environment (e.g., agroecological systems that nurture ecosystems, maximize biodiversity, and rebuild soil fertility). In other words, the challenge is to see the impacts as part of a complex social-ecological system, and to retain that systemic view when it comes to defining imperatives and solutions at the science-policy interface.

Steps to address the environmental impacts of agriculture (including climate mitigation and adaptation measures) are also steps to address the human health impacts of agriculture — and are doubly urgent.

CHALLENGE 6:
ADDRESSING THE FOOD-HEALTH-POVERTY NEXUS:
SEEING HEALTH IMPACTS IN THEIR SOCIO-ECONOMIC CONTEXT

Health impacts in food systems are also rooted in complex and deep-seated socio-economic drivers, as seen across the impact channels. Understanding these connections and breaking these cycles is a precondition for meaningful and effective action to address health impacts in food systems.

The various dimensions of poverty — including material deprivation and social exclusion — make it a major determinant of health. Strong associations have also been shown between inequality and a range of negative social-health outcomes, irrespective of absolute wealth (Wilkinson and Pickett, 2010). Poverty and inequality not only exacerbate the likelihood of food-related health impacts, but can also increase their severity: people in poverty are less likely to have the resources to deal with the health conditions they incur. The trends are self-reinforcing over time. Poverty can lead to undernourishment, and undernourished people may suffer from lower productivity, making their earnings potential even lower and keeping them trapped in poverty. Poverty and

inequality are therefore key compounding factors in several of the severest health impacts associated with food systems. Poverty is universally recognized as a key driver of food insecurity, and is a major contributing factor to poor dietary health, obesity, and the associated risks of NCDs (see impact channels 4 and 5). There has been increasing recognition that hunger is fundamentally a distributional question tied to poverty, social exclusion, and other factors affecting access to and utilization of food (WHO, 2008; World Bank, 2010; FAO, 2015). These understandings have been forged most eloquently by Amartya Sen (1981, 1983), who argued that hunger is not due so much to a lack of food, but to a lack of “entitlements” and “access” relating to inequalities built into mechanisms for distributing food. As seen in Section 2, food insecurity is not limited to poor countries: discussion around access to food has allowed this reality to be recognized and understood (Riches, 1997; Riches and Silvasti, 2014).

Poverty can also exacerbate the health risks in food systems via poor sanitation conditions. Those living in hazardous locations prone to flooding or landslides, close to waste sites, and without access to clean water and sanitation are generally among the poorest in society (Whitmee et al., 2015). Unsanitary conditions can exacerbate a range of health risks in food systems, e.g., facilitating the spread of foodborne disease throughout the chain and in the home, or raising the risks of pesticide poisoning on-farm.

Food systems drive poverty and inequality in a variety of ways. First and foremost, food systems have perpetuated poverty conditions through precarious employment and low monetary compensation for many farmers, farmworkers, and foodworkers. The vast majority of poor people in the world, anywhere, are engaged in agriculture and other food production and distribution activities. A report by the ILO estimates that “most jobs in rural areas do not ensure sufficient levels of income for workers to afford adequate food for themselves and their families” (ILO, 2015b, as cited in Anderson and Athreya, 2015). Another study indicated that food preparation and service workers (#1), dishwashers (#2), and farmworkers (#7) are among the lowest-paid groups in the United States (Bureau of Labor Statistics, 2012). Food systems also help to create the underlying unsanitary conditions that afflict poor communities around the world, e.g., through widespread environmental contamination of water sources via agricultural runoff, and through overuse of often scarce water resources.

In other words, the food-health nexus is also a food-health-poverty nexus, and health impacts in food systems cannot be seen in isolation from socio-economic drivers. However, seeing these connections and breaking these cycles is a major challenge. Poverty is locked into the fabric of the prevailing industrial food and farming model. Over decades, various policies and imperatives have co-evolved to create what may be described as a “cheap food” model or “low-cost food system” (De Schutter, 2017; Wallinga, 2009). Production subsidies, trade liberalization, and a range of other measures have been put in place

Poverty and inequality not only exacerbate the likelihood of food-related health impacts, but can also increase their severity: people in poverty are less likely to have the resources to deal with the health conditions they incur.

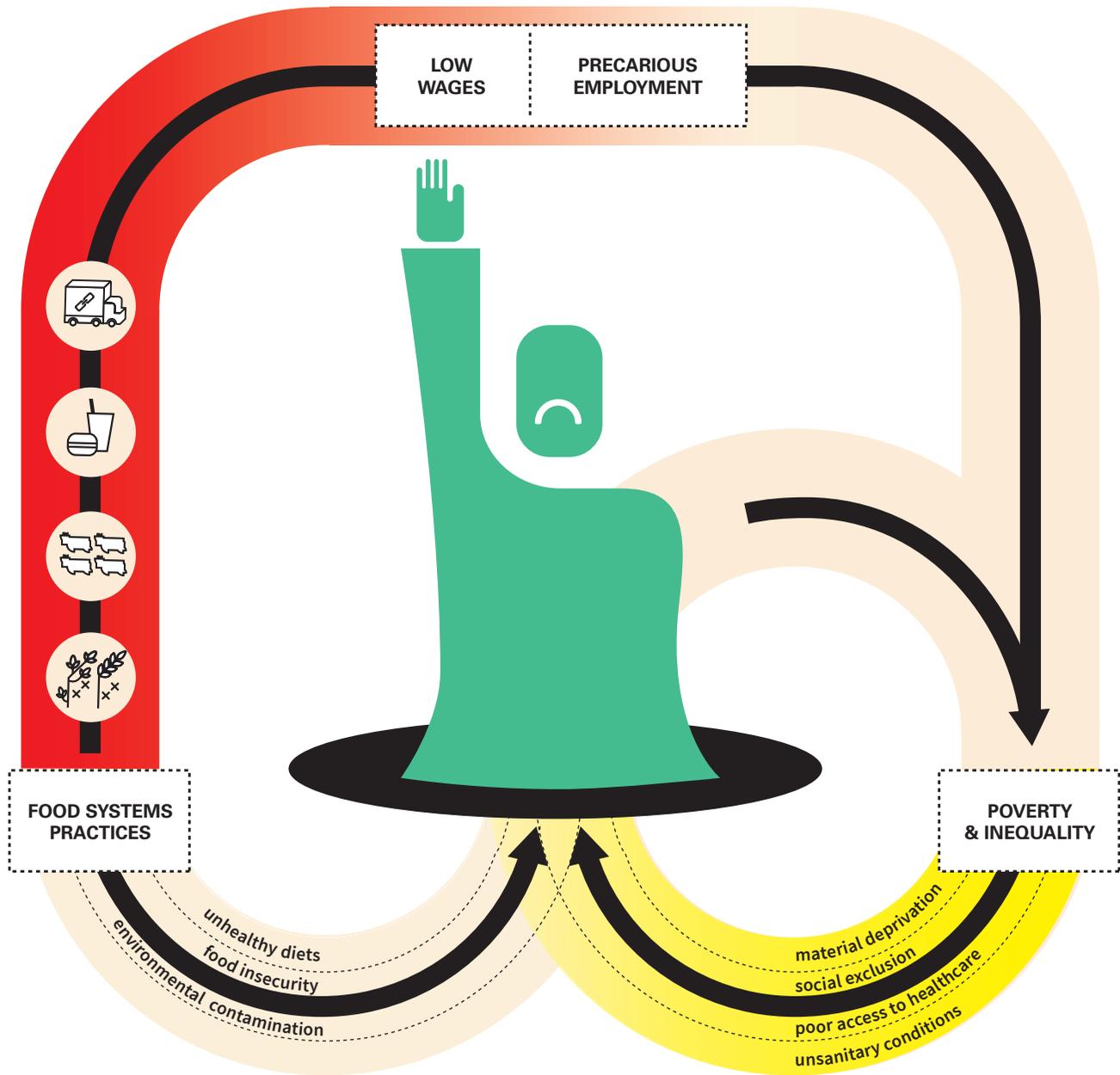


Fig. 7: The Food-Health-Poverty nexus

Poverty is perpetuated by the low-cost commodity production underpinning modern food systems. In turn, poverty exacerbates diet-related diseases, food insecurity, and other health risks in food systems.

with a view to producing large volumes of cheap commodity crops. Livelihood pressures for farmers, downward cost pressures across the food system, and systematic exposure to occupational hazards have been accepted as the *quid pro quo* for a system that guaranteed a stable food supply, particularly for urban populations. Moreover, cheap food has allowed workers to be paid relatively low wages in the manufacturing sector, acting as a de facto social policy, i.e., compensating for non-remunerative work (De Schutter, 2017; IPES-Food, 2016). Cheap food has even been traded off against environmental contamination; agro-chemical firms have argued against restrictions on pesticide use on the grounds that it will push up production costs and ultimately food prices (Furlong, 2016). In wealthier countries, the share of income spent on food has plummeted, and the expectation of cheap food has become highly embedded (see IPES-Food, 2016), further locking in the industrial low-cost model, despite its spiralling health and environmental impacts.

Over decades, various policies and imperatives have co-evolved to create what may be described as a “cheap food” model or “low-cost food system.”

The challenge, therefore, is not only to pay attention to poverty as a driver of health risks in food systems, but to avoid one-dimensional approaches that address only a specific manifestation of poverty (i.e., inability to access sufficient calories) while reproducing the conditions in which poverty — and a range of associated health risks — are likely to persist. This calls attention to the need to address food systems and the economic model underpinning them in a holistic manner, and to ensure that alternative visions for delivering food security — without sacrificing other health goals — are brought to light.

CHALLENGE 7: COMMUNICATING COMPLEXITY AND BUILDING A HEALTHIER DEBATE AT THE SCIENCE-POLICY INTERFACE

As described above, the health impacts of food systems are often complex, mutually reinforcing, and compounded by factors such as climate change and poverty. Communicating this complexity and interconnectedness is one of the greatest challenges in order to pave the way for responding appropriately to the problems identified in Section 2, requiring a nuanced discussion of risk and uncertainty at the science-policy interface.

A range of food-related health risks tends to be brought to public attention, but nuance and context is often lost, while misunderstandings tend to be propagated and reinforced across a range of fora and actors. For example, media reporting on diets/nutrition is often focussed unduly on single studies taken out of their context (Goldberg and Hellwig, 1997; Jensen, 2008), and tends to simplify and misrepresent results to make stronger statements than the original research article (Chang, 2015; Pellechia, 1997). New findings on the

suspected carcinogenicity of food items are particularly prone to “single study syndrome,” loss of nuance, and failure to place specific risks in their broader context. Long-term cumulative effects have been confused with immediate acute risks in coverage of cases such as the “Alar” apple growth regulator scandal in the United States, undermining key understandings about food system risks (McCluskey and Swinnen, 2011). These trends feed into an already polarized public debate that tends to view foods either as all-powerful healers or toxic killers, where pre-conceptions (e.g., trust/distrust of “technology”) are strong and tend to colour people’s interpretation of new “facts” (Chang, 2015; McCluskey and Swinnen, 2011).

In some cases, political reactions to health scares or controversies have failed to place risks in a broader context, tending to subjugate scientific detail to more emotive narratives. This pattern was particularly apparent in countries with strong carnivore traditions after the publication of the opinion of the International Agency for Research on Cancer on the carcinogenicity of red and processed meats (see Impact Channel 4). A Facebook post by an Austrian government official read that “placing ham on the same level as asbestos is outrageous nonsense and only serves to unsettle people. There’s no doubt for me: Austria’s sausage is and remains the best” (AFP, 2015). In other cases, simplistic and sometimes mistaken explanations for health scares have been rapidly propagated in the face of uncertain and/or complex environmental contamination pathways. For example, unusual smog occurrence in the United Kingdom in March–April 2014 was widely attributed to “Sahara dust” in the media and by policymakers; however, a meteorological study concluded that the elevated rates of airborne particulate matter were largely driven by ammonium nitrate stemming from continental Europe’s agricultural ammonia emissions (Vieno et al., 2016).

Failure to place risks in a meaningful context can also be traced back to the scientific literature itself, and the focus on delivering new and potentially media-genic findings. For example, “statistically significant” associations between various foods and cancer (sometimes both positive and negative for the same foods) are now so commonplace that major questions must be asked about the validity and implications of the findings (Ioannidis, 2016; Jackson and Ormerod, 2017). Meanwhile, the results of epidemiological studies have been found to be continually cited in the scientific literature even after failures to replicate initial findings (Ioannidis, 2016).

When attempts are made to communicate complexity/uncertainty, and to revisit existing evidence, this can itself be seized upon to discredit the whole debate. For example, when new findings emerge that contradict previously reported numbers, industry groups have run advertisements that denounce the entire scientific dialogue (e.g., around obesity) as baseless “hype” (Mayer and Joyce,

2005; McHugh, 2006). With different foods in the crosshairs and different types of risk rising and falling in seemingly arbitrary ways, nutrition scientists have been portrayed as frequently “changing their minds” about advice on which products, in which quantities, one should consume in a healthy diet (Goldberg and Hellwig, 1997; Jensen, 2008). In this context, people become generally less trusting of scientists and their recommendations, and less motivated to implement lifestyle changes (Chang, 2015), even in non-controversial matters such as exercising and eating fruit and vegetables (Nagler, 2014). These factors exacerbate the already-strong cognitive bias to discount risk information (Hoek, 2015). Others might react with extreme avoidance tactics. Simply avoiding foods associated with a health risk is a “lower-cost solution” than trying to obtain fuller information (McCluskey and Swinnen, 2011). In other cases, perceived complexity/uncertainty has been seized upon to suggest that consumers are ill-equipped to decide what is safe to eat. For example, industry campaigns, e.g., to defend High-Fructose Corn Syrup (HFCS), have been critiqued for promoting a “deficit” model whereby only medical professionals (i.e., “experts”) are capable of understanding nutritional risks (Heiss, 2013).

The proliferating and fragmented fora in which food and health are discussed also present challenges in terms of building a nuanced discussion around food system risks and finding a common vocabulary for doing so. Distinct and non-interacting discourses can be identified in highly siloed academic communities, journals, magazines, and public discussion fora, each with its own problem diagnosis and emphases, its own body of evidence, and underpinned by highly divergent worldviews. For example, research on the allergenic risks of processed foods has been embraced within alternative and naturopathic health sectors, while barely featuring elsewhere; successes in phasing out nontherapeutic antibiotic use in intensive livestock holdings in Northern Europe tends to be limited to agricultural journals, thereby failing to reach and engage with the public health community (Burke, 2012; Zinsstag et al., 2012). A rapidly shifting media landscape, and particularly the accessing of news via social media, has raised the risks of people forming their understandings within “echo chambers” in which the choices of one’s friends and contacts acts as a filter, and highly opinionated and “fake news” abound. People’s attention to source credibility is even lower for internet-sourced news than for traditional media (McCluskey and Swinnen, 2011). Some 61% of millennials source their news from Facebook, making it the most-used source of information, according to a 2015 poll in the United States (Mitchell et al., 2015).

It is challenging to forge meaningful dialogue in this context, or to confront different assumptions and worldviews. For example, for those with greater faith in industrial-scale solutions and global supply chains, the key stake in fighting food insecurity might be to biofortify crops, and the key step in overcoming foodborne disease risks might be to increase biosecurity in industrial

The proliferating and fragmented fora in which food and health are discussed also present challenges in terms of building a nuanced discussion around food system risks and finding a common vocabulary for doing so.

holdings and raise traceability requirements in global supply chains. However, for others, the solution might be to move away from global food systems and to build “food sovereignty,” allowing farmers — so prevalent among the food insecure — to improve their livelihoods and avoid the multiple health risks of globalized systems. Arguments of the first type can be articulated in relation to specific risks to be addressed in specific policy areas (e.g., agriculture, research, development), while arguments based on systemic alternatives and new economic paradigms may not find a corresponding policy framework or forum. As a result, paradigms for risk management will be premised on expansion of the global supply chains, trading regimes, and broader industrial model for which and through which current approaches and current policies have been defined, rather than held up against alternatives. This calls attention to the importance of ensuring the right policy frameworks for governing food systems in order to ensure a healthy and democratic debate.

Evidence gaps, incomplete transmission of scientific evidence to the broader public, misleading narratives, and non-interacting discourses therefore converge to create a climate in which specific risks and uncertainties take on disproportionate importance, others are systematically obscured, and the general ability to grasp the functioning of food systems is undermined. Building a new basis for discussing and communicating food system risks is therefore a pressing challenge, requiring action on multiple fronts.



SECTION 4

IDENTIFYING LEVERAGE POINTS FOR BUILDING HEALTHIER FOOD SYSTEMS

As described in this report, many of the health impacts of food systems trace back to specific industrial food and farming practices, e.g., intensive livestock production and chemical-intensive agriculture. Reforming these practices is essential. In its first thematic report, “From Uniformity to Diversity,” IPES-Food (2016) identified a paradigm shift toward diversified agroecological systems as the key to addressing the negative environmental and social impacts of our food systems. Diversified, agroecological systems refer to a model based on diversifying farms and farming landscapes, replacing chemical inputs with organic matter, optimizing biodiversity, and stimulating interactions between different species, as part of holistic strategies to build long-term fertility, healthy agro-ecosystems, and secure livelihoods. IPES-Food found this model to have major potential to deliver strong and stable yields, health-promoting food and farming systems, environmental resilience, and secure farming livelihoods, thereby succeeding where current (industrial) food systems are failing. The analysis in the present paper underlines the case for this paradigm shift. Indeed, improving human health outcomes is a potentially promising entry point for sparking this transition, given the wealth of evidence supporting action on this front, the breadth of people exposed to these risks, and the mounting costs of inaction.

However, the key question is how such a transition can occur. As the discussion above has shown, current paradigms and power relations are deeply entrenched and self-reinforcing. The pathway from evidence to understanding to action

faces a series of obstacles. Moreover, some modes of action embed ways of thinking that may erode the basis for addressing health impacts in sufficiently systemic ways. Through prevailing narratives and “solutions,” different problems continue to be disconnected from one another and from their underlying drivers, reinforcing the view that these are discrete problems to be solved by targetted actions to plug the gaps in the edifice. Health is continually split from other aspects of sustainability (e.g., environmental integrity), although they are intimately linked. Moreover, prevailing approaches tend to be premised on further industrialization, granting an increasingly important role to those with the technological capacity and economies of scale to generate data, assess risks, and deliver key health fixes (e.g., biofortification, highly traceable and biosecure supply chains). The governance structures of food systems — reflecting long-standing priorities, path dependencies, and policy silos — are ill-adapted to address the systemic and interconnected risks emerging from them. This in turn shapes the design of scientific research, reinforcing a focus on specific disciplines and specific causal relationships rather than system-wide risks and systemic alternatives, which are thus excluded from the science-policy interface and disconnected from mainstream debate. Power — to achieve visibility, to frame narratives, to set the terms of debate, and to influence policy — is at the heart of this nexus. Indeed, as the industrial model is further entrenched, a narrow group of actors is able to exercise ever-greater control over data provision and scientific research priorities, as well as continuing to shape the narratives and solutions. Meanwhile, those most affected by the health impacts in food systems become increasingly marginal in the process. The low visibility of the problems affecting poor and marginalized groups (particularly indigenous communities, migrant workers, and small-scale farmers in the Global South) allows the cultural disconnect between food and agriculture to grow. This in turn makes people less attuned to the real costs of their food. Public communication of health risks further narrows the lens, often reducing food to specific nutrients — to something safe or toxic — and obscuring the people and the production systems behind it.

In this context, even the more obvious steps to address these risks — e.g., levelling up to the best practices and closing regulatory gaps between different countries — are not as simple as they sound. Various health risks continue to occur systematically in various locations, sectors, and nodes of global supply chains. The industrial food and farming model that systematically generates these impacts also generates narratives, imperatives, and power relations that obscure its social and environmental fallout, and reinvent industrial agriculture as the solution. The failure to level up may therefore reflect a region or country's disadvantaged position within global food systems, and modes of political priority-setting that fail to capture or address the health impacts affecting those with low power and visibility. To different extents and in continually evolving ways, countries have accepted trade-offs (e.g., between investment and regulation) that are driven and sustained by other participants in global food systems

Improving human health outcomes is a potentially promising entry point for sparking this transition, given the wealth of evidence supporting action, the breadth of people exposed to these risks, and the mounting costs of inaction.

(e.g., multinational food companies, foreign governments and international organizations, and consumers in other parts of the world). These choices may also reflect the assumption that further industrialization of food systems is inevitable, and that systemic alternatives do not exist or are simply unviable.

Furthermore, there are limits to “levelling up” in a context of global, system-wide risks. For example, once antimicrobial-resistant bacteria have moved from livestock to human populations, they tend to proliferate widely. Steps to ban specific antibiotics for agriculture in specific locations can at best defend an imperfect status quo (reducing the chances of future AMR events) but require parallel steps elsewhere, and a global systemic shift to curb antibiotic usage in agriculture and other settings (Chang et al., 2015).

The challenge, therefore, is not merely to address the under-prioritized impacts, but to address the ways in which priorities are set and impacts are traded off against one another. In other words, what is required is nothing short of revisiting the fundamental pillars and underlying assumptions of the industrial food and farming model. The evidence on food system impacts must continue to grow, providing an ever-stronger basis for action. But in parallel, we need a new basis for reading, interpreting, and acting on that evidence, in all of its complexity. Steps to build understanding of the interconnected nature of food systems and to build a healthy science-policy interface may therefore be just as important as steps to reform food system practices. Indeed, this may be a condition for those reforms to occur.

The five leverage points identified below are proposed to help break the current cycles, addressing the deficits of public awareness, scientific evidence, and political will in combination. Collectively, steps to address these leverage points can provide a new basis for action to build healthier food systems.

What is required is nothing short of revisiting the fundamental pillars and underlying assumptions of the industrial food and farming model.

LEVERAGE POINT 1: PROMOTING FOOD SYSTEMS THINKING

Food systems thinking is both a means (a way of bringing the different problems and their connections to light) and an end (i.e., a basis for acting on the risks we face). Food systems thinking must be promoted at all levels, i.e., we must systematically bring to light the multiple connections between different health impacts, between human health and ecosystem health, between food, health, poverty, and climate change, and between social and environmental sustainability. Only when health risks are viewed in their entirety, across the food system and on a global scale, can we adequately assess the priorities, risks, and trade-offs underpinning our food systems, e.g., the provision of low-cost

food versus the systematic poverty conditions faced by small-scale farmers and foodworkers, and the environmental fallout of the industrial model.

These understandings must be built and reinforced among a variety of actors. For example, political and scientific “silos” tend to mirror one another and must collectively be overcome (i.e., policymakers must request scientific advice of a systemic nature, and these more integrated approaches must find a political audience and policy forum). Moreover, a healthy science-policy interface requires a broad basis of public understanding and awareness, and this in turn requires a healthy public debate in which scientific evidence is transmitted accurately and consistently (e.g., via news media), understanding of risk and uncertainty is rebuilt, and faith in science is itself re-established.

Promoting understanding of the multiple interconnected dimensions of sustainability is a key step toward food systems thinking, and a prerequisite for building a basis of support for the type of holistic action that is required. For example, precautionary action to prevent specific practices that undermine soil fertility will only gain widespread acceptance if the links between soil health, ecosystem health, and human health are more broadly recognized. Promoting understanding of the breadth of health impacts across food systems, and their links to underlying factors such as poverty and inequality, is also crucial in order to weigh up key trade-offs. Furthermore, the international dimensions of these health impacts must be recognized and systematically brought to light, in order to capture the full scope of the problem, bring understandings into line with the global, cross-border nature of food systems and their fallout, and to reconnect people with the realities of the food on their plates.

All of this has profound implications for the way that knowledge is developed and deployed in our societies, requiring a shift toward interdisciplinarity and transdisciplinarity in a range of contexts. Higher education programs are already seeing some evolution toward systems analysis, higher-order thinking, and new approaches to collecting, managing, and interpreting data (O’Brien et al., 2013). Many universities have recently opened Food System Centres or Units that tend to break down the traditional silo structures of research. Concepts such as “ecological public health” (Lang, 2011), “planetary health” (Whitmee et al., 2015), and “One Health” (Cunningham et al., 2017) offer useful frameworks and a new vocabulary for unifying the different dimensions of sustainability. The notion of “foodscapes” has also emerged as a comprehensive framework for investigating how food, places, and people are interconnected and how, in turn, food environments may affect public health (Mikkelsen, 2011). The “sustainable diets” concept also seeks to bridge these divides (Burlingame and Dernini, 2011; Macdiarmid et al., 2012). These frameworks can help to promote holistic scientific discussions and pave the way for equally integrated policy approaches.

Food systems thinking can also be encouraged on a smaller scale, equipping people with the knowledge and understandings to ask questions about the food they eat, and to make sense of the information they receive. School curricula at all levels could include modules that integrate the multiple dimensions of food systems, including hands-on experiential programs such as school gardens, food preparation facilities, and making meals a time for learning as much as for eating. Participation in community-supported agriculture and similar initiatives could also help to bridge the gap between producers and consumers, and to rebuild a broad basis of knowledge about food systems.

LEVERAGE POINT 2: REASSERTING SCIENTIFIC INTEGRITY AND RESEARCH AS A PUBLIC GOOD

Research priorities, structures, and capacities need to be fundamentally realigned with principles of public interest and public good, and the nature of the challenges we face (i.e., cross-cutting sustainability challenges and systemic risks). Encouraging food systems thinking (Leverage Point 1) may help to preserve scientific integrity: less siloed and more systemic approaches in scientific and political discussion may make it harder for specific actors to continue to separate the problems from one another and to frame the debate around narrowly defined, one-dimensional solutions. Scientific integrity could also be bolstered through changes in the rules governing scientific journals, e.g., around disclosure of conflicts of interest, and steps to make that information more visible (see Box 6). To address the problem at root, measures may also be required to reduce the reliance of researchers on private funding. Initiatives to fund and mandate independent scientific research and independent journalism on the health impacts of food systems (and on broader food systems impacts) are needed. Support could also be channelled to research and reporting that shines a light on industry-sponsored science, the role of industry front groups, and misinformation campaigns. Securing the necessary resources may require innovative funding models and the involvement of a range of public and private actors (e.g., philanthropies). Reflection is also required on the role of trade associations and industry-linked information portals and “front groups,” which may have greater capacity than public health agencies to communicate around food-related health risks, but also face key conflicts of interest and tend to blur the boundary between industry and education (Heiss, 2013).

Different forms of research involving a wider range of actors and sources of knowledge are also required to rebalance the playing field and challenge prevailing problem framings (e.g., industry-leaning approaches; a “Global North” bias; approaches that exclude impacts on certain populations). For example,

Less siloed and more systemic approaches in scientific and political discussion may make it harder for specific actors to continue to separate the problems from one another and to frame the debate around narrowly defined, one-dimensional solutions.

participatory research, which includes the people whose health is most affected by food systems, can help to overcome narrow research questions that exclude impacts on certain populations. Encouraging a broader shift in research modalities, however, requires different incentives across academia. It also requires assurances that studies of this type will not be relegated to inferior or anecdotal status, and will be considered side-by-side with other types of inquiry, forming a meaningful part of the evidence base for assessing food systems.

Participatory research, which includes the people whose health is most affected by food systems, can help to overcome narrow research questions that exclude impacts on certain populations.

Further investment in large-scale data gathering by intergovernmental organizations should be supported. The WHO-led Initiative to Estimate the Global Burden of Foodborne Diseases offers an example of collaborative data generation and capacity-building in ways that help to address the “Global North” bias in scientific knowledge. This initiative was launched in 2006, and after a decade-long effort was able to publish an authoritative estimate of the global foodborne disease burden in 2015, while also drawing considerable stakeholder attention to this problem (WHO, 2015a). Another example of a global initiative that aims to redress the imbalance in regional data availability is the mapping of poverty and likely zoonoses hotspots by the International Livestock Research Institute (ILRI et al., 2012), one of the CGIAR research centres.

Box 6

REFORMING EDITORIAL STANDARDS TO COUNTER INDUSTRY BIAS

Concerns about scientific integrity and conflicts of interest of industry-funded studies have long plagued the academic community. In response, some medical and nutrition journals have taken steps beyond standard financial interest disclosure to reduce the publication of potentially biased research. They include the following (Lesser, 2009):

- 1) Require authors to disclose both financial and non-financial (that is, personal, political, academic, ideological, or religious) competing interests that occurred within 5 years of the commencement of the research [*PLoS Medicine* policy (The PLoS Medicine Editors, 2008)].
- 2) Require that all clinical trials and observational studies (including nutrition trials) be registered in an appropriate public trials registry upon initiation of the study [*American Journal of Clinical Nutrition* policy (AJCN, n.d.)].
- 3) Prohibit the publication of review articles and editorials — which comment on published articles but do not present new research — by authors with significant financial interest in any company relevant to the topics and products discussed in the article [*New England Journal of Medicine* policy (Drazen and Curfman, 2002)].

- 4) In addition to any statistical analyses performed by the sponsoring industry, require that statistical analyses be independently conducted by researchers who are not employed by the sponsor [*JAMA: the Journal of the American Medical Association* policy (Fontanarosa et al., 2005)].

The *JAMA* policy in particular sparked considerable backlash from industry representatives who alleged the imposition of an unfair double standard (Loew, 2005; Rothman and Evans, 2005), and triggered a rumoured boycott of *JAMA* by industry (Wager et al., 2010). Indeed, a later analysis showed that after the policy change, the total number of published Randomized Control Trials (RCTs), particularly industry-funded or industry-supported RCTs, decreased significantly in *JAMA*, while it continued to remain steady or increase in journals that had not imposed a similar policy (Wager et al., 2010). While the policy may have been effective for *JAMA*, the simultaneous increase of industry-funded research in rival journals suggests that such steps may only reach public interest goals if they are taken discipline-wide. Others argue that industry bias is more likely represented in authors asking the “right questions” rather than interfering with the statistical analysis, which would limit the effectiveness of additional oversight (Smith, 2005).

LEVERAGE POINT 3: BRINGING THE ALTERNATIVES TO LIGHT

Although the evidence base on negative health impacts faces several challenges and complexities, these impacts are nonetheless being increasingly documented, studied, and valued (in terms of human and economic costs). Less is known about the positive health impacts and positive externalities of alternative food and farming systems (e.g., agroecological crop and livestock management approaches that build soil nutrients, sequester carbon in the soil, or restore ecosystem functions such as pollination and water purification).

The environmental impacts of organic production (and the implications for long-term productivity) are being increasingly documented, and form part of the growing evidence base on alternative systems. Evidence on the health impacts of organic production is also growing. For example, a recent systematic literature review concluded that both organic milk and meat contain around 50% more beneficial omega-3 fatty acids than their conventional equivalents (Średnicka-Tober et al., 2016a; Średnicka-Tober et al., 2016b). However, important knowledge gaps remain and must be addressed through further studies. For example, compositional differences have regularly been found between organic and conventionally produced items, but long-term cohort studies showing these differences translating into human health benefits are still lacking (Baránski et al., 2017).

It is also important to gather and compare information more holistically on the outcomes of different food and farming models (including but not limited to organic). In particular, attention is required to the “diversified agroecological” systems described above. While these alternative systems take a variety of forms, are referred to with different terminologies, and feature in dispersed literatures, a growing body of evidence is nonetheless forming around them (IPES-Food, 2016). Some specific gaps still remain in regard to their health implications. For example, studies linking soil health and human health remain rare (Brevik and Sauer, 2015; Knez and Graham, 2013). However, identifying health impacts may be less important than documenting the combined and mutually reinforcing benefits of alternative systems. It is crucial to: document and communicate the potential of diversified agroecological systems to reconcile productivity gains, environmental resilience, social equity, and health benefits; strengthen yields on the basis of rehabilitating ecosystems (not at their expense); build nutrition on the basis of access to diverse foods; and, to redistribute power and reduce inequalities in the process (IPES-Food, 2016). These outcomes must be seen as a package and as a new basis for delivering health — one in which healthy people and a healthy planet are co-dependent.

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A complete picture of the alternatives also requires more documentation of real-life experimentation at the policy level to support food system alternatives (see, for example, forthcoming case studies from IPES-Food¹³, and the Beacons of Hope project¹⁴). As summarized in the Lancet Series on Maternal Health and Nutrition (Ruel and Alderman, 2013), there is a dearth of evidence on the nutritional effects of many interventions, including agricultural and rural development programs, social safety nets (e.g., cash transfer programs), and even school nutrition education programs. Information is also lacking on the effectiveness of soda taxes and a range of other steps taken to build healthier food environments (Garnett et al., 2015). Real-life policy experimentation can foster the “adaptive management” advocated by natural resource scholars (Lee, 1994), and can provide useful insights into how political economy obstacles can be overcome, and how priorities can be shifted at the science-policy interface (e.g., by forming new alliances, by generating new evidence or bringing it to bear in different ways).

A solid information base on alternative food systems — how they perform, and how they can be effectively promoted through policy — can challenge the assumption that an ever-more industrial logic is the only solution for addressing health impacts in food systems, and can help to overcome the TINA (“there is no alternative”) syndrome, whereby practices with known negative effects are able to continue unchallenged.

LEVERAGE POINT 4: ADOPTING THE PRECAUTIONARY PRINCIPLE

The health impacts of food systems reviewed in this report are multifactorial and at the population level. They are caused by many agents, and often reinforce each other through various mechanisms, transiting through factors like climate change, unsanitary conditions, and poverty, which are themselves shaped by food systems activities and impacts. While determining definite and unique causes of a particular health condition is rarely possible, approaches to establishing causality in epidemiology — and the definition of “cause” — have made significant advances (Broadbent, 2009; De Vreese, 2009; Parascandola, 2011). The single-cause model may still be suitable for the study of infectious diseases (i.e., in which the presence of an agent is necessary and often sufficient to establish causation) but does not work well for the analysis of chronic diseases, which requires a multifactorial analysis of one or more agents (causes), the host (individuals’ characteristics), and the environment. Diseases are attributable to various (sometimes overlapping) causal mechanisms, acting together, no one of which may be sufficient or necessary to cause a given disease (Krieger, 1994; McGwin, 2010). Those different component causes are *risk factors* affecting the probability of the disease to occur in the population

(and raising uncertainties in complex systems). It is thus inappropriate to look for a solitary, unique, and definite cause for these conditions, or to set a benchmark of “scientifically incontestable evidence” (like for single-cause diseases) as a basis for action in food systems. From this perspective, disease prevention must increasingly be understood in terms of identifying specific risk factors (not *the* cause) by the accumulation of evidence from many different studies from many different disciplines (Hill, 1965; Ioannidis, 2016). It is the collective strength, consistency, plausibility, and coherence of these studies that establishes a given agent as a major risk factor in a disease.

This complexity is real and challenging, but cannot be an excuse for inaction. The precautionary principle in guiding policy was developed exactly for situations such as these. It requires policymakers to weigh the collective evidence on risk factors and act accordingly. For example, from a perspective of accumulated evidence, there may already be a strong basis for action where environmental contamination is concerned. Although causal inference cannot be established for EDCs, researchers have amassed compelling evidence of EDC effects in lab cells as well as in wild animals; this, combined with ubiquitous exposure and increased incidence of EDC-related diseases in humans, can be enough justification for urgent precautionary action. Indeed, the evidence gaps described in Impact Channel 2 did not prevent the Endocrine Society, on the basis of a comprehensive literature review, concluding that recent data “removes any doubt that EDCs are contributing to increased chronic disease burdens related

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Box 7

THE PRECAUTIONARY PRINCIPLE

The precautionary principle (PP) lowers the threshold for action by governments in the context of scientific controversy and the acquisition of new knowledge (Jiang, 2014; Von Schomberg, 2012). In simple terms, it states that “where there are threats to serious or irreversible damage, lack of full certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” and human health risks (UN, 1992). The origins of the PP can be found in German and Swedish law (Löfstedt, 2004). It was enshrined in European law in the EU’s Maastricht Treaty of 1992 (Jiang, 2014). Here, it is commonly associated with a “reversed burden of proof,” which requires applicants to demonstrate conclusively that potentially noxious products are harmless before being approved for use (Löfstedt, 2004). It has henceforth been cited in the regulation of a wide range of products and imports, from hormones in beef to pharmaceuticals and pesticides. The normative and discretionary nature of the PP has led to considerable criticism, particularly by the business community and foreign trade partners who fear its use as a protectionist non-tariff barrier (Löfstedt, 2004). In response, in 2000, the European Union published

the Communication on the Precautionary Principle that further defines the parameters of application: “The precautionary principle applies where scientific evidence is insufficient, inconclusive, or uncertain and preliminary scientific evaluation indicates that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal, or plant health may be inconsistent with the high level of protection chosen by the EU” (European Commission, 2000). The Communication also states that the principles of proportionality, non-discrimination, consistency, examination of costs and benefits, and examination of scientific developments shall apply. European case law shows that the burden of proof has differed significantly in cases where the PP has been invoked, though this is mainly due to differences in the strength of precaution applied at Member State level or written in secondary legislation (Jiang, 2014). Some analysts claim that the cost of regulation is causing a swing back to regulatory impact analysis (Löfstedt, 2004) and argue that the European Union’s regulatory decisions closely mirror those of the United States, irrespective of their different regulatory philosophies (Wiener et al., 2010).

to obesity, diabetes mellitus, reproduction, thyroid, cancers, and neuroendocrine and neurodevelopmental functions” (Gore et al., 2015, p. 601).

**LEVERAGE POINT 5:
BUILDING INTEGRATED FOOD POLICIES
UNDER PARTICIPATORY GOVERNANCE**

Policy processes must be up to the task of managing the complexity of food systems and the systemic health risks they generate. Integrated food policies and food strategies are required to overcome the traditional biases in sectoral policies (e.g., export orientation in agricultural policy) and to align various policies with the objective of delivering environmentally, socially, and economically sustainable food systems. Frameworks for managing health risks, such as the “precautionary principle,” can be meaningfully and consistently deployed within integrated food policies, in line with the objectives described above.

Trade-offs can also be captured and addressed in a single policy framework. For example, a food policy could allow the trade-offs of the cheap food economy to be weighed and addressed in ways that an agricultural policy cannot. Full Cost Accounting or True Cost Accounting approaches can help to bring to light the true cost of cheap food, and to consider where these costs fall and the extent to which they offset any pro-poor impacts of the current model; indeed, as indicated in this report, many health impacts and their costs fall disproportionately on the poor — particularly in societies where health-care costs are not mutualized. Food policies can and must unlock the food-health-poverty nexus in order to drive meaningful progress in addressing food system health risks.

Integrated food policies can also provide a forum for long-term systemic objectives to be set, e.g.: mapping out a sequenced transition away from industrial food and farming systems; reducing the chemical load in food and farming systems; devising strategies for tackling emerging risks such as antimicrobial resistance and climate-related threats (e.g., shifting zoonotic risks, threats to productivity); managing scarce resources such as freshwater in the face of competing demands from agriculture, industry, and other uses; and, bringing agriculture and fisheries (particularly aquaculture) together under one roof to reflect on the collective challenges of protein availability and ecosystem management.

These processes must be participatory. Beyond the organization and the formation of alliances, beyond lobbying and advocacy efforts, members of the public must find institutional ways to participate in governance, and

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governance mechanisms must find institutional ways to include the breadth of affected populations. Governments around the world face difficult choices on healthcare, with increasing demands on limited resources. Meaningful stakeholder participation in governance is essential for transparency in setting the right priorities, developing appropriate policies, implementing programs effectively, and for monitoring results. Greater stakeholder participation in governance is needed to guarantee policy that is driven not only by evidence, but also by ethics and the broader public interest. Broader public awareness of and engagement with health risks in food systems is likely to be crucial in order to generate a greater understanding and acceptance of the basis on which decisions are being taken. This is particularly important when it comes to applying precautionary approaches (see Leverage Point 4) or considering the implications of particular policies, such as trade and investment agreements, for public health (McNeill et al, 2017). Rather than considering these as distant, technocratic exercises, the general public must become a partner in public risk management and priority-setting, and buy into the rationale and priorities underpinning it. The institutionalization of such participation can also help prevent the undue influence of powerful groups in decision-making.

Meaningful integration of food policies and meaningful participation in governance could take different forms, and more studies are needed to examine different processes. Examples emerging in the past twenty years include experiments with municipal Food Policy Councils in North America, and the formation of Food and Nutrition Security Councils in Brazil as spaces for participation of civil society in policy discussion, design, implementation, and monitoring. The project launched by IPES-Food in 2016, “Towards a Common Food Policy for the EU,” seeks to create such a policy process at the European level.

The monumental task of building healthier food systems requires more democratic and more integrated ways of managing risk and governing food systems. A range of actors — policymakers, big and small private sector firms, healthcare providers, environmental groups, consumers’ and health advocates, farmers, agri-food workers, and citizens — must collaborate and take shared ownership in this endeavour.



THE WAY FORWARD

Food systems affect human health in a variety of ways, often with severe consequences. This report has sought to describe and identify the key impacts individually, within specific channels and collectively as part of a broader “food-health nexus” — the web of interactions, imperatives and understandings at the intersection of food and health. The report has shown that building healthier food systems requires ambitious and wide-ranging actions. The five leverage points identified suggest a series of steps: to reconnect the worlds of food production and food consumption; to reconnect the different problems with each other and with their underlying drivers; to rebalance power and bring all health impacts to light; and, to institute more democratic and more integrated ways of managing risk and governing food systems. In other words, a new basis of understanding and a new basis for political action are required in order to unravel the food-health nexus and pave the way for healthier outcomes.

Around the world, movement in this direction is already occurring. Meaningful steps are being taken to close the reporting gaps in food systems; holistic counter-narratives are showing through the cracks; people are reconnecting with the realities of how their food is produced; and decisive actions are being taken on the basis of what we already know. The challenge is to keep the whole picture in view, to foster increasingly joined-up approaches, to build the basis of understanding and action in parallel, and to bring health alongside environmental integrity and social equity as the common requirements of the sustainable food systems of the future.

Building healthier food systems requires ambitious and wide-ranging actions. A new basis of understanding and a new basis for political action are required in order to unravel the food-health nexus and pave the way to healthier outcomes.

ENDNOTES

- 1 A detailed description of the food systems approach employed by IPES-Food can be found in the panel's first report, "The New Science of Sustainable Food Systems: Overcoming Barriers to Food Systems Reform" (2015): http://www.ipes-food.org/images/Reports/IPES_report01_1505_web_br_pages.pdf.
- 2 Acute pesticide poisoning refers to the severe poisoning that occurs after exposure to a single dose of pesticide, for instance through ingestion or skin contact, as opposed to chronic pesticide poisoning, which occurs as a result of repeated, small, non-lethal doses over a long period of time.
- 3 Some of the strongest evidence regarding hematopoietic cancers points to an association between pesticide exposure and non-Hodgkin's lymphoma (Eriksson et al., 2008; Fagioli et al., 1994; Spinelli et al., 2007), leukemia (Hoffmann et al., 2008; Kristensen et al., 1996; Van Maele-Fabry et al., 2008), and multiple myeloma (Kristensen et al., 1996; Nanni et al., 1998; Pottern et al., 1992; Viel and Richardson, 1993). For solid tumours, the most consistent positive associations have been found between occupational exposure and brain cancer, for instance in France (Provost et al., 2007; Viel et al., 1998), the United States (Kross et al., 1996; Samanic et al., 2008), Sweden (Rodvall et al., 1996), and Italy (Figà-Talamanca et al., 1993).
- 4 On-farm injury risks have been associated with machinery (Bancej and Arbuckle, 2000; Goldcamp et al., 2004; McCurdy et al., 2004; Meiers and Baerg, 2001), tractors and other vehicles (Carlson et al., 2005; Cole et al., 2006; Goldcamp et al., 2004; Jones and Bleeker, 2005; Little et al., 2003; Marlenga et al., 2006; Rautiainen and Reynolds, 2002), the handling of livestock (Franklin and Davies, 2003; Lindsay et al., 2004; Solomon et al., 2007; Sprince et al., 2003), and falls from machinery and farm structures (Alexe et al., 2003; Pickett et al., 2005; Sosnowska and Kostka, 2007).
- 5 The key conditions to which these workers are exposed include numbness; musculoskeletal symptoms in the neck-shoulder region, shoulders, wrists, and lower back; Raynaud's disease, and cold symptoms.
- 6 Farmer suicides in India have been frequently associated with cotton farming, a non-food crop; however, cotton farmers are likely to be subject to the typical livelihood stresses running across agricultural commodity systems, making this an impact of relevance here.
- 7 Blue-baby syndrome is a potentially life-threatening condition that decreases the blood's ability to distribute oxygen in the body.
- 8 While impacting health through environmental contamination, EDCs are also linked to health impacts as occupational hazards (Impact Channel 1) and contaminated foods (Impact Channel 3).
- 9 The key mechanisms that have been identified are mutagenic effects (direct changes to the DNA); endocrine effects (that promote the proliferation of abnormal cell clones); and immunotoxic effects (which disturb cancer surveillance mechanisms).
- 10 For one, it may not be clear which food product led to the illness; the food may be "complex," made up of many ingredients out of which only one was contaminated (Pires et al., 2011); commodities may become contaminated with many agents, which complicates the detection process; the transmission and infection rates may vary according to the food product, pathogen, and demographic make-up of the consuming population; and transmission can occur by non-food mechanisms, such as the water used to prepare the food (Morris, 2011; Scallan et al., 2011b; WHO, 2015a). It is thus difficult to effectively determine whether the global incidence rate of foodborne disease outbreak has increased or decreased in recent years.

- 11 Processed meat was classified as carcinogenic to humans (Group 1), based on “sufficient evidence in humans that the consumption of processed meat causes colorectal cancer.” Press Communication IARC: https://www.iarc.fr/en/media-centre/pr/2015/pdfs/pr240_E.pdf
- 12 By May 2017, this text had been removed from the EPA website following executive orders from the Trump Administration to redefine the agency’s work.
- 13 A forthcoming report from IPES-Food (due for completion in 2018) will compile a series of case studies of agroecological transition at a variety of scales (farm-level, community-level, regional and national).
- 14 The Beacons of Hope initiative aims to highlight successful transitions toward sustainable, diversified food systems and provide a framework documenting their key characteristics, impacts, and pathways in order to inspire replication across regions and scales. The final report is expected to be released in 2018. More: <https://futureoffood.org/priority-initiatives/beacons-of-hope>.

BIBLIOGRAPHY

- ABC Australia, 2008. Farmers' suicide rates double national average: study [WWW Document]. ABC News. URL <http://www.abc.net.au/news/2008-08-19/farmers-suicide-rates-double-national-average-study/482170> (accessed 11.2.16).
- AFP, 2015. Worst case scenario: Germany and Austria defend their sausages. *The Guardian*. <https://www.theguardian.com/lifeandstyle/2015/oct/27/wurst-germany-austria-defend-sausages-who-report-cancer-processed-meats>.
- African Union Commission, NEPAD Planning and Coordinating Agency, UN Economic Commission for Africa, UN World Food Programme, 2014. The Cost of Hunger in Africa: Social and Economic Impact of Child Undernutrition in Egypt, Ethiopia, Swaziland and Uganda. UNECA, Addis Ababa.
- Agarwal, B, 2014. "Food Security, Productivity and Gender Inequality," in R. Herring (ed). *Handbook of Food, Politics and Society* (New York: Oxford University Press).
- Ahmed, A.M., Shimamoto, T., 2015. Molecular characterization of multidrug-resistant *Shigella* spp. of food origin. *Int. J. Food Microbiol.* 194, 78–82. doi:10.1016/j.ijfoodmicro.2014.11.013
- Ahonen, E.Q., Porthé, V., Vázquez, M.L., García, A.M., López-Jacob, M.J., Ruiz-Frutos, C., Ronda-Pérez, E., Benach, J., Benavides, F.G., ITSAL Project, 2009. A qualitative study about immigrant workers' perceptions of their working conditions in Spain. *J. Epidemiol. Community Health.* 63, 936–942. doi:10.1136/jech.2008.077016
- AJCN, n.d. AJCN Information for authors: Research registration and required checklists [WWW Document]. *Am. J. Clin. Nutr.* URL http://ajcn.nutrition.org/site/misc/ifa_register.xhtml (accessed 1.15.17).
- Alamgir, H., Swinkels, H., Yu, S., Yassi, A., 2007. Occupational injury among cooks and food service workers in the healthcare sector. *Am. J. Ind. Med.* 50, 528–535. doi:10.1002/ajim.20475
- Alasbali, T., Smith, M., Geffen, N., Trope, G.E., Flanagan, J.G., Jin, Y., Buys, Y.M., 2009. Discrepancy between results and abstract conclusions in industry- vs nonindustry-funded studies comparing topical prostaglandins. *Am. J. Ophthalmol.* 147, 33–38.e2. doi:10.1016/j.ajo.2008.07.005
- Alavanja, M.C.R., Samanic, C., Dosemeci, M., Lubin, J., Tarone, R., Lynch, C.F., Knott, C., Thomas, K., Hoppin, J.A., Barker, J., Coble, J., Sandler, D.P., Blair, A., 2003. Use of agricultural pesticides and prostate cancer risk in the Agricultural Health Study cohort. *Am. J. Epidemiol.* 157, 800–814.
- Alexe, D.M., Petridou, E., Dessypris, N., Skenderis, N., Trichopoulos, D., 2003. Characteristics of farm injuries in Greece. *J. Agric. Saf. Health.* 9, 233–240. doi:10.13031/2013.13688
- Ali, U., Syed, J.H., Malik, R.N., Katsoyiannis, A., Li, J., Zhang, G., Jones, K.C., 2014. Organochlorine pesticides (OCPs) in South Asian region: A review. *Sci. Total Environ.* 476–477, 705–717. doi:10.1016/j.scitotenv.2013.12.107
- Anderson, G.H., 2006. Sugar-containing beverages and post-prandial satiety and food intake. *Int. J. Obes.* 30, S52–S59. doi:10.1038/sj.ijo.0803493
- Anderson, M., Athreya, B., 2015. Improving the Well-Being of Food System Workers, in: Global Alliance for the Future of Food (Ed.), *Advancing Health and Well-Being in Food System: Strategic Opportunities for Funders*. Global Alliance for the Future of Food.
- Anderson, M.E., Sobsey, M.D., 2006. Detection and occurrence of antimicrobially resistant *E. coli* in groundwater on or near swine farms in eastern North Carolina. *Water Sci. Technol. J. Int. Assoc. Water Pollut. Res.* 54, 211–218.
- Anema, A., Vogenthaler, N., Frongillo, E.A., Kadiyala, S., Weiser, S.D., 2009. Food insecurity and HIV/AIDS: Current knowledge, gaps, and research priorities. *Curr. HIV/AIDS Rep.* 6, 224–231.
- Annals of Oncology, 2007. The burden and cost of cancer. *Ann. Oncol.* 18, iii8–iii22. doi:10.1093/annonc/mdm097
- Anthony, M., Williams, J.M., Avery, A.M., 2008. Health needs of migrant and seasonal farmworkers. *J. Community Health Nurs.* 25, 153–160. doi:10.1080/07370010802221768
- Arcury, T.A., Quandt, S.A., 2007. Delivery of health services to migrant and seasonal farmworkers. *Annu. Rev. Public Health.* 28, 345–363. doi:10.1146/annurev.publhealth.27.021405.102106

- Attina, T.M., Hauser, R., Sathyanarayana, S., Hunt, P.A., Bourguignon, J.-P., Myers, J.P., DiGangi, J., Zoeller, R.T., Trasande, L., 2016. Exposure to endocrine-disrupting chemicals in the USA: A population-based disease burden and cost analysis. *Lancet Diabetes Endocrinol.* 4, 996–1003. doi:10.1016/S2213-8587(16)30275-3
- Bachman, C.M., Baranowski, T., Nicklas, T.A., 2006. Is there an association between sweetened beverages and adiposity? *Nutr. Rev.* 64, 153–174.
- Bahia, L., Coutinho, E.S.F., Barufaldi, L.A., Abreu, G. de A., Malhão, T.A., de Souza, C.P.R., Araujo, D.V., 2012. The costs of overweight and obesity-related diseases in the Brazilian public health system: Cross-sectional study. *BMC Public Health.* 12, 440. doi:10.1186/1471-2458-12-440
- Bailey, R.L., West, K.P., Black, R.E., 2015. The epidemiology of global micronutrient deficiencies. *Ann. Nutr. Metab.* 66, 22–33. doi:10.1159/000371618
- Bancej, C., Arbuckle, T., 2000. Injuries in Ontario farm children: A population based study. *Inj. Prev.* 6, 135–140. doi:10.1136/ip.6.2.135
- Barnes, D.E., Bero, L.A., 1996. Industry-funded research and conflict of interest: An analysis of research sponsored by the tobacco industry through the Center for Indoor Air Research. *J. Health Polit. Policy Law.* 21, 515–542.
- Baron, S.L., Habes, D., 1992. Occupational musculoskeletal disorders among supermarket cashiers. *Scand. J. Work. Environ. Health.* 18, 127–129.
- Barrett, C.B., 2010. Measuring food insecurity. *Science.* 327, 825–828. doi:10.1126/science.1182768
- Barrientos, S., Knorrington, P., Evers, B., Visser, M., Opondo, M., 2016. Shifting regional dynamics of global value chains: Implications for economic and social upgrading in African horticulture. *Environ. Plan. A* 48, 1266–1283. doi:10.1177/0308518X15614416
- Bassil, K.L., Vakil, C., Sanborn, M., Cole, D.C., Kaur, J.S., Kerr, K.J., 2007. Cancer health effects of pesticides. *Can. Fam. Physician.* 53, 1704–1711.
- Basu, S., Yoffe, P., Hills, N., Lustig, R.H., 2013. The relationship of sugar to population-level diabetes prevalence: An econometric analysis of repeated cross-sectional data. *PLoS ONE.* 8, e57873. doi:10.1371/journal.pone.0057873
- Berkowitz, G.S., Wetmur, J.G., Birman-Deych, E., Obel, J., Lapinski, R.H., Godbold, J.H., Holzman, I.R., Wolff, M.S., 2004. In utero pesticide exposure, maternal paraoxonase activity, and head circumference. *Environ. Health Perspect.* 112, 388–391.
- Bero, L.A., 2005. Tobacco industry manipulation of research. *Public Health Rep.* 120, 200–208.
- Beshwari, M.M.M., Bener, A., Ameen, A., Al-Mehdi, A.M., Ouda, H.Z., Pasha, M.A.H., 1999. Pesticide-related health problems and diseases among farmers in the United Arab Emirates. *Int. J. Environ. Health Res.* 9, 213–221. doi:10.1080/09603129973182
- Bes-Rastrollo, M., Schulze, M.B., Ruiz-Canela, M., Martinez-Gonzalez, M.A., 2013. Financial conflicts of interest and reporting bias regarding the association between sugar-sweetened beverages and weight gain: A systematic review of systematic reviews. *PLoS.* 10. doi:10.1371/journal.pmed.1001578
- Bhandari, M., Busse, J.W., Jackowski, D., Montori, V.M., Schünemann, H., Sprague, S., Mears, D., Schemitsch, E.H., Heels-Ansdell, D., Devereaux, P.J., 2004. Association between industry funding and statistically significant pro-industry findings in medical and surgical randomized trials. *Can. Med. Assoc. J.* 170, 477–480.
- Blainey, M., Ganzleben, C., Goldenman, G., Pratt, I., 2008. The benefits of strict cut-off criteria on human health in relation to the proposal for a regulation concerning plant protection products (No. IP/A/ENVI/ST/2008-18), Policy Department Economic and Scientific Policy. European Parliament, Brussels.
- Boden, L.I., Ozonoff, A., 2008. Capture-recapture estimates of nonfatal workplace injuries and illnesses. *Ann. Epidemiol.* 18, 500–506. doi:10.1016/j.annepidem.2007.11.003
- Bricas, N., Lamine, C., Casabianca, F., 2013. *Agricultures et alimentations: Des relations à repenser?* *Nat. Sci. Sociétés.* 21, 66–70. doi:10.1051/nss/2013084

- Broadbent, A., 2009. Causation and models of disease in epidemiology. *Stud. Hist. Philos. Biol. Biomed. Sci.* 40, 302–311. doi:10.1016/j.shpsc.2009.09.006
- Brown, J.L., Shepard, D., Martin, T., Orwat, J., 2007. The Economic Cost of Domestic Hunger: Estimated Annual Burden to the United States. Sodexo Foundation, Boston.
- Brownell, K.D., Frieden, T.R., 2009. Ounces of prevention: The public policy case for taxes on sugared beverages. *N. Engl. J. Med.* 360, 1805–1808. doi:10.1056/NEJMp0902392
- Brownell, K.D., Warner, K.E., 2009. The perils of ignoring history: Big tobacco played dirty and millions died. How similar is big food? *Milbank Q.* 87, 259–294. doi:10.1111/j.1468-0009.2009.00555.x
- Brumby, S., Kennedy, A., Chandrasekara, A., 2013. Alcohol consumption, obesity, and psychological distress in farming communities — An Australian study. *J. Rural Health Off. J. Am. Rural Health Assoc. Natl. Rural Health Care Assoc.* 29, 311–319. doi:10.1111/jrh.12001
- Bucher Della Torre, S., Keller, A., Laure Depeyre, J., Kruseman, M., 2016. Sugar-sweetened beverages and obesity risk in children and adolescents: A systematic analysis on how methodological quality may influence conclusions. *J. Acad. Nutr. Diet.* 116, 638–659. doi:10.1016/j.jand.2015.05.020
- Bureau of Labor Statistics, 2013. International Comparisons of Annual Labor Force Statistics, 1970–2012. United States Department of Labor, Washington, D.C.
- Bureau of Labor Statistics, 2012. Employment and wages for the highest and lowest paying occupations, May 2012 [WWW Document]. Occup. Employ. Stat. URL https://www.bls.gov/oes/2012/may/high_low_paying.htm
- Burlingame, B., Dernini, S., 2011. Sustainable diets: The Mediterranean diet as an example. *Public Health Nutr.* 14, 2285–2287. doi:10.1017/S1368980011002527
- Butland, B., Jebb, S., Kopelman, P., McPherson, K., Thomas, S., Mardell, J., Parry, V., 2007. Tackling Obesity: Future Choices — Project Report. Government Office for Science of the United Kingdom, London.
- Cabello, F.C., 2006. Heavy use of prophylactic antibiotics in aquaculture: A growing problem for human and animal health and for the environment. *Environ. Microbiol.* 8, 1137–1144. doi:10.1111/j.1462-2920.2006.01054.x
- Callejon, R.M., Rodriguez-Naranjo, M.I., Ubeda, C., Hornedo-Ortega, R., Garcia-Parrilla, M.C., Troncoso, A.M., 2015. Reported foodborne outbreaks due to fresh produce in the united states and european union: Trends and causes. *Foodborne Pathog. Dis.* 12, 32–38. doi:10.1089/fpd.2014.1821
- Campbell, D., 1998. Health hazards in the meatpacking industry. *Occup. Med. Phila.* Pa 14, 351–372.
- Canyon, D.V., Speare, R., Burkle, F.M., 2016. Forecasted impact of climate change on infectious disease and health security in Hawaii by 2050. *Disaster Med. Public Health Prep.* 10, 797–804. doi:10.1017/dmp.2016.73
- Caraher, M., Coveney, J., 2004. Public health nutrition and food policy. *Public Health Nutr.* 7, 591–598. doi:10.1079/PHN2003575
- Caritas Australia, 2015. What causes food insecurity? [WWW Document]. Caritas Aust. URL <http://www.caritas.org.au/learn/blog/blog-detail?ID=542a5e5c-22fb-446c-a4f5-cc7df-b2c1650> (accessed 8.15.17).
- Carlson, K.F., Gerberich, S.G., Church, T.R., Ryan, A.D., Alexander, B.H., Mongin, S.J., Renier, C.M., Zhang, X., French, L.R., Masten, A., 2005. Tractor-related injuries: A population-based study of a five-state region in the Midwest. *Am. J. Ind. Med.* 47, 254–264. doi:10.1002/ajim.20135
- Carozza, S.E., Li, B., Elgethun, K., Whitworth, R., 2008. Risk of childhood cancers associated with residence in agriculturally intense areas in the United States. *Environ. Health Perspect.* 116, 559–565. doi:10.1289/ehp.9967
- Casey, J.A., Curriero, F.C., Cosgrove, S.E., Nachman, K.E., Schwartz, B.S., 2013. High-density livestock operations, crop field application of manure, and risk of community-associated methicillin-resistant *Staphylococcus aureus* infection in Pennsylvania. *JAMA Intern. Med.* 173, 1980–1990. doi:10.1001/jamainternmed.2013.10408

- Cassini, A., Colzani, E., Kramarz, P., Kretzschmar, M.E., Takkinen, J., 2016. Impact of food and water-borne diseases on European population health. *Curr. Opin. Food Sci.* 12, 21–29. doi:10.1016/j.cofs.2016.06.002
- Castleman, T., Bergeron, G., Ivers, L., 2015. Food Security and Program Integration: An Overview, in: *Food Insecurity and Public Health*. CRC Press, pp. 1–22. doi:10.1201/b18451-2
- Cawley, J., Meyerhoefer, C., 2012. The medical care costs of obesity: An instrumental variables approach. *J. Health Econ.* 31, 219–230. doi:10.1016/j.jhealeco.2011.10.003
- CDC, 2013. Antibiotic Resistance Threats in the United States, 2013. Centres for Disease Control and Prevention, Atlanta.
- Centres for Disease Control and Prevention, U.S., 1996. Spontaneous abortions possibly related to ingestion of nitrate-contaminated well water — LaGrange County, Indiana, 1991–1994 [WWW Document]. *Cent. Dis. Control Prev. Dep. Health Hum. Serv.* URL <http://www.cdc.gov/mmwr/preview/mmwrhtml/00042839.htm> (accessed 3.8.16).
- Chan, J., DeMelo, M., Gingras, J., Gucciardi, E., 2015. Challenges of diabetes self-management in adults affected by food insecurity in a large urban centre of Ontario, Canada. *Int. J. Endocrinol.* 2015, e903468. doi:10.1155/2015/903468
- Chan, M., 2016. Obesity and diabetes: The slow-motion disaster. Keynote address at the 47th meeting of the National Academy of Medicine, Washington, DC, 17 October by Dr. Margaret Chan, Director-General of the World Health Organization.
- Chang, C., 2015. Motivated processing: How people perceive news covering novel or contradictory health research findings. *Sci. Commun.* 37, 602–634. doi:10.1177/1075547015597914
- Chang, Q., Wang, W., Regev-Yochay, G., Lipsitch, M., Hanage, W.P., 2015. Antibiotics in agriculture and the risk to human health: How worried should we be? *Evol. Appl.* 8, 240–245. doi:10.1111/eva.12185
- Chau, N.D.G., Sebesvari, Z., Amelung, W., Renaud, F.G., 2015. Pesticide pollution of multiple drinking water sources in the Mekong Delta, Vietnam: Evidence from two provinces. *Environ. Sci. Pollut. Res.* 22, 9042–9058. doi:10.1007/s11356-014-4034-x
- Chaudhry, Q., Scotter, M., Blackburn, J., Ross, B., Boxall, A., Castle, L., Aitken, R., Watkins, R., 2008. Applications and implications of nanotechnologies for the food sector. *Food Addit. Contam. Part Chem. Anal. Control Expo. Risk Assess.* 25, 241–258. doi:10.1080/02652030701744538
- Chia, V.M., Li, Y., Quraishi, S.M., Graubard, B.I., Figueroa, J.D., Weber, J.-P., Chanock, S.J., Rubertone, M.V., Erickson, R.L., McGlynn, K.A., 2010. Effect modification of endocrine disruptors and testicular germ cell tumour risk by hormone-metabolizing genes. *Int. J. Androl.* 33, 588–596. doi:10.1111/j.1365-2605.2009.00975.x
- Cole, 2006. Occupational health hazards of agriculture, in: Hawkes, C., Ruel, M.T. (Eds.), *Understanding the Links between Agriculture and Health*. International Food Policy Research Institute (IFPRI), Washington, D.C.
- Cole, H.P., Myers, M.L., Westneat, S.C., 2006. Frequency and severity of injuries to operators during overturns of farm tractors. *J. Agric. Saf. Health.* 12, 127–138.
- Cook, G., 2010. Sweet talking: Food, language, and democracy. *Lang. Teach.* 43, 168–181. doi:10.1017/S0261444809990140
- Corvalan, C.F., Driscoll, T.R., Harrison, J.E., 1994. Role of migrant factors in work-related fatalities in Australia. *Scand. J. Work. Environ. Health.* 20, 364–370.
- Crain, D.A., Janssen, S.J., Edwards, T.M., Heindel, J., Ho, S., Hunt, P., Iguchi, T., Juul, A., McLachlan, J.A., Schwartz, J., Skakkebaek, N., Soto, A.M., Swan, S., Walker, C., Woodruff, T.K., Woodruff, T.J., Giudice, L.C., Guillette, L.J., 2008. Female reproductive disorders: The roles of endocrine-disrupting compounds and developmental timing. *Fertil. Steril.* 90, 911–940. doi:10.1016/j.fertnstert.2008.08.067
- Crisostomo, L., Molina, V.V., 2002. Pregnancy outcomes among farming households of Nueva Ecija with conventional pesticide use versus integrated pest management. *Int. J. Occup. Environ. Health.* 8, 232–242. doi:10.1179/107735202800338812

- Cristea, A., Hummels, D., Puzzello, L., Avetisyan, M., 2013. Trade and the greenhouse gas emissions from international freight transport. *J. Environ. Econ. Manag.* 65, 153–173. doi:10.1016/j.jeem.2012.06.002
- Cunningham, A.A., Scoones, I., Wood, J.L.N., 2017. One health for a changing world: New perspectives from Africa. *Phil Trans R Soc B.* 372, 20160162. doi:10.1098/rstb.2016.0162
- Dalin, C., Rodríguez-Iturbe, I., 2016. Environmental impacts of food trade via resource use and greenhouse gas emissions. *Environ. Res. Lett.* 11, 35012. doi:10.1088/1748-9326/11/3/035012
- Dalrymple, D.G., 2008. International agricultural research as a global public good: Concepts, the CGIAR experience and policy issues. *J. Int. Dev.* 20, 347–379. doi:10.1002/jid.1420
- Dan-Hassan, M.A., Olasehinde, P.I., Amadi, A.N., Yisa, J., Jacob, J.O., 2012. Spatial and temporal distribution of nitrate pollution in groundwater of Abuja, Nigeria. *Int. J. Chem.* 4, 104. doi:10.5539/ijc.v4n3p104
- Darnton-Hill, I., Webb, P., Harvey, P.W.J., Hunt, J.M., Dalmiya, N., Chopra, M., Ball, M.J., Bloem, M.W., de Benoist, B., 2005. Micronutrient deficiencies and gender: Social and economic costs. *Am. J. Clin. Nutr.* 81, 1198S–1205S. doi:10.1093/ajcn/81.5.1198S [pii]
- Das, A., 2011. Farmers' suicide in India: Implications for public mental health. *Int. J. Soc. Psychiatry.* 57, 21–29. doi:10.1177/0020764009103645
- Das, R., Steege, A., Baron, S., Beckman, J., Harrison, R., 2001. Pesticide-related illness among migrant farm workers in the United States. *Int. J. Occup. Environ. Health* 7, 303–312. doi:10.1179/107735201800339272
- Davidson, P., 2015. Fast-food workers strike, seeking \$15 wage, political muscle. *USA Today.*
- De Blok, B.M.J., Vlieg-Boerstra, B.J., Oude Elberink, J.N.G., Duiverman, E.J., DunnGalvin, A., Hourihane, J.O.B., Cornelisse-Vermaat, J.R., Frewer, L., Mills, C., Dubois, A.E.J., 2007. A framework for measuring the social impact of food allergy across Europe: A EuroPrevall state of the art paper. *Allergy Eur. J. Allergy Clin. Immunol.* 62, 733–737. doi:10.1111/j.1398-9995.2006.01303.x
- De Brún, A., McCarthy, M., McKenzie, K., McGloin, A., 2015. Examining the media portrayal of obesity through the lens of the common sense model of illness representations. *Health Commun.* 30, 430–440. doi:10.1080/10410236.2013.866390
- De Schutter, O., 2017. The political economy of food systems reform. *Eur. Rev. Agric. Econ.* 44, 705–731. doi:10.1093/erae/jbx009
- De Vreese, L., 2009. Epidemiology and causation. *Med. Health Care Philos.* 12, 345–353. doi:10.1007/s11019-009-9184-0
- Dich, J., Wiklund, K., 1998. Prostate cancer in pesticide applicators in Swedish agriculture. *The Prostate.* 34, 100–112.
- Djulgovic, B., Lacevic, M., Cantor, A., Fields, K.K., Bennett, C.L., Adams, J.R., Kuderer, N.M., Lyman, G.H., 2000. The uncertainty principle and industry-sponsored research. *Lancet Lond. Engl.* 356, 635–638. doi:10.1016/S0140-6736(00)02605-2
- Dolan, C.S., 2004. On farm and packhouse: Employment at the bottom of a global value chain. *Rural Sociol.* 69, 99–126. doi:10.1526/003601104322919928
- Done, H.Y., Venkatesan, A., Halden, R.U., 2015. Does the recent growth of aquaculture create antibiotic resistance threats different from those associated with land animal production in agriculture? *Am. Assoc. Pharm. Sci. J.* 17, 513–524. doi:10.1208/s12248-015-9722-z
- Dongre, A.R., Deshmukh, P.R., 2012. Farmers' suicides in the Vidarbha region of Maharashtra, India: A qualitative exploration of their causes. *J. Inj. Violence Res.* 4, 2–6. doi:10.5249/jivr.v4i1.68
- Doyle, M.P., Erickson, M.C., Alali, W., Cannon, J., Deng, X., Ortega, Y., Smith, M.A., Zhao, T., 2015. The food industry's current and future role in preventing microbial foodborne illness within the United States. *Clin. Infect. Dis.* 1–8. doi:10.1093/cid/civ253
- Drazen, J.M., Curfman, G.D., 2002. Financial Associations of Authors. *N. Engl. J. Med.* 346, 1901–1902. doi:10.1056/NEJMe020074
- Drewnowski, A., Darmon, N., Briend, A., 2004. Replacing fats and sweets with vegetables and fruits: A question of cost. *Am. J. Public Health.* 94, 1555–1559.

- Eddleston, M., Karalliedde, L., Buckley, N., Fernando, R., Hutchinson, G., Isbister, G., Konradsen, F., Murray, D., Piola, J.C., Senanayake, N., Sheriff, R., Singh, S., Siwach, S.B., Smit, L., 2002. Pesticide poisoning in the developing world: A minimum pesticides list. *Lancet Lond. Engl.* 360, 1163–1167.
- Efird, J.T., Holly, E.A., Preston-Martin, S., Mueller, B.A., Lubin, F., Filippini, G., Peris-Bonet, R., McCredie, M., Cordier, S., Arslan, A., Bracci, P.M., 2003. Farm-related exposures and childhood brain tumours in seven countries: Results from the SEARCH International Brain Tumour Study. *Paediatr. Perinat. Epidemiol.* 17, 201–211.
- Eldridge, D., Jackson, R., Rajashekara, S., Piltch, E., Begay, M.-G., VanWassenhove, J., Jim, J., Abeita, J., Daye, L., Joe, L., Williams, M., Castillo, M., Miller-Castillo, M., Begaye, S., Tully, V., Shin, S., 2015. Understanding Food Insecurity in Navajo Nation through the Community Lens, in: Ivers, L. (Ed.), *Food Insecurity and Public Health*. CRC Press, pp. 155–174. doi:10.1201/b18451-9
- Eller, D., 2017. With Water Works’ lawsuit dismissed, water quality is the legislature’s problem. Moines Regist.
- Elver, H., 2017. Report of the Special Rapporteur on the right to food, UN doc. A/HRC/34/48. United Nations Human Rights Council, Geneva.
- Endogenous Hormones and Breast Cancer Collaborative Group, Key, T.J., Appleby, P.N., Reeves, G.K., Roddam, A.W., 2010. Insulin-like growth factor 1 (IGF1), IGF binding protein 3 (IGFBP3), and breast cancer risk: Pooled individual data analysis of 17 prospective studies. *Lancet Oncol.* 11, 530–542. doi:10.1016/S1470-2045(10)70095-4
- Engler-Stringer, R., 2010. Food, cooking skills, and health: A literature review. *Can. J. Diet. Pract. Res. Publ. Dietit. Can. Rev. Can. Prat. Rech. En Diet. Une Publ. Diet. Can.* 71, 141–145. doi:10.3148/71.3.2010.141
- Eriksson, M., Hardell, L., Carlberg, M., Akerman, M., 2008. Pesticide exposure as risk factor for non-Hodgkin lymphoma including histopathological subgroup analysis. *Int. J. Cancer.* 123, 1657–1663. doi:10.1002/ijc.23589
- European Commission, 2014. Prospects for EU agricultural markets and income 2014–2024. European Commission, Brussels.
- European Commission, 2000. Communication from the Commission on the Precautionary Principle. The Commission of the European Communities, Brussels.
- Ezquerro-Cañete, A., 2016. Poisoned, dispossessed and excluded: A critique of the neoliberal soy regime in Paraguay. *J. Agrar. Change.* 16, 702–710. doi:10.1111/joac.12164
- Fagioli, F., Rigolin, G.M., Cuneo, A., Scapoli, G., Spanedda, R., Cavazzini, P., Castoldi, G., 1994. Primary gastric lymphoma: Distribution and clinical relevance of different epidemiological factors. *Haematologica.* 79, 213–217.
- FAO, 2016. Methods for Estimating Comparable Rates of Food Insecurity Experienced by Adults Throughout the World. Food and Agriculture Organization of the United Nations, Rome.
- FAO, 2011. Why Has Africa Become a Net Food Importer? Explaining Africa Agricultural and Food Trade Deficits. Food and Agriculture Organization of the United Nations, Rome.
- FAO, 2004. The State of Agricultural Commodity Markets: 2004. Food and Agriculture Organization of the United Nations, Rome.
- FAO, 2000. The Elimination of Food Insecurity in the Horn of Africa. Final Report. Food and Agriculture Organization of the United Nations, Rome.
- FAO/IFAD/WFP, 2015. State of Food Insecurity in the World. Food and Agriculture Organization of the United Nations, Rome.
- Fawole, W.O., Özkan, B., 2017. Comprehensive review of growing food insecurity in Africa in terms of causes, effects and solutions: The Nigerian example. *Turk. J. Agric. Food Sci. Technol.* 5, 629–636. doi:10.24925/turjaf.v5i6.629-636.1113
- FCWA, 2012. The Hands that Feed Us: Challenges and Opportunities for Workers Along the Food Chain. The Food Chain Workers’ Alliance.
- FDA, 2015. Final Determination Regarding Partially Hydrogenated Oils. U.S. Food and Drug Administration, Washington, D.C.

- FDA, 2014. Final Guidance for Industry: Assessing the Effects of Significant Manufacturing Process Changes, Including Emerging Technologies, on the Safety and Regulatory Status of Food Ingredients and Food Contact Substances, Including Food Ingredients that Are Color Additives. U.S. Food and Drug Administration, Washington, D.C.
- Fernández-Luqueño, F., López-Valdez, F., Gamero-Melo, P., Luna-Suárez, S., Aguilera-González, E.N., Martínez, A.I., García-Guillermo, M.D.S., Hernández-Martínez, G., Herrera-Mendoza, R., Álvarez-Garza, M.A., Pérez-Velázquez, I.R., 2013. Heavy metal pollution in drinking water: A global risk for human health: A review. *Afr. J. Environ. Sci. Technol.* 7, 567–584.
- Feskens, E.J.M., Sluik, D., van Woudenberg, G.J., 2013. Meat consumption, diabetes, and its complications. *Curr. Diab. Rep.* 13, 298–306. doi:10.1007/s11892-013-0365-0
- Fetsch, R.J., 2014. Managing Stress, Anger, Anxiety, and Depression on Dairy Farms. Presented at the High Plains Dairy Conference.
- Feychting, M., Plato, N., Nise, G., Ahlbom, A., 2001. Paternal occupational exposures and childhood cancer. *Environ. Health Perspect.* 109, 193–196.
- Figà-Talamanca, I., Mearelli, I., Valente, P., Bascherini, S., 1993. Cancer mortality in a cohort of rural licensed pesticide users in the province of Rome. *Int. J. Epidemiol.* 22, 579–583.
- Fishwick, D., Pearce, N., D'Souza, W., Lewis, S., Town, I., Armstrong, R., Kogevinas, M., Crane, J., 1997. Occupational asthma in New Zealanders: A population-based study. *Occup. Environ. Med.* 54, 301–306.
- Fontanarosa, P.B., Flanagin, A., DeAngelis, C.D., 2005. Reporting conflicts of interest, financial aspects of research, and role of sponsors in funded studies. *JAMA.* 294, 110–1. doi:10.1001/jama.294.1.110
- Food Foundation, 2016. EVIDENCE PAPER. Food Environment Policy Index (Food-Epi) for England. The Food Foundation, London.
- Forshee, R.A., Anderson, P.A., Storey, M.L., 2008. Sugar-sweetened beverages and body mass index in children and adolescents: A meta-analysis. *Am. J. Clin. Nutr.* 87, 1662–1671.
- Francis, C., Lieblein, G., Gliessman, S., Breland, T.A., Creamer, N., Harwood, R., Salomonsson, L., Helenius, J., Rickerl, D., Salvador, R., Wiedenhoef, M., Simmons, S., Allen, P., Altieri, M., Flora, C., Poincelot, R., 2003. Agroecology: The ecology of food systems. *J. Sustain. Agric.* 22, 99–118. doi:10.1300/J064v22n03_10
- Francis, C.A., 2004. Education in agroecology and integrated systems. *J. Crop Improv.* 11, 21–43. doi:10.1300/J411v11n01_02
- Frank, A.L., McKnight, R., Kirkhorn, S.R., Gunderson, P., 2004. Issues of agricultural safety and health. *Annu. Rev. Public Health.* 25, 225–245. doi:10.1146/annurev.publhealth.25.101802.123007
- Franklin, R.C., Davies, J.N., 2003. Farm-related injury presenting to an Australian base hospital. *Aust. J. Rural Health.* 11, 292–302.
- Fraser, C.E., Smith, K.B., Judd, F., Humphreys, J.S., Fragar, L.J., Henderson, A., 2005. Farming and mental health problems and mental illness. *Int. J. Soc. Psychiatry.* 51, 340–349.
- French, S., Morris, P., 2006. Assessing the evidence for sugar-sweetened beverages in the aetiology of obesity: A question of control. *Int. J. Obes.* 30, S37–S39. doi:10.1038/sj.ijo.0803490
- Furlong, H., 2016. Europeans Want Cheap, Pesticide-Free Food; Industry Campaign Says It Can't Be Done [WWW Document]. Sustain. Brands. URL http://www.sustainablebrands.com/news_and_views/supply_chain/hannah_furlong/europeans_want_cheap_pesticide-free_food_industry_campaig (accessed 8.6.17).
- Garshick, E., Laden, F., Hart, J.E., Rosner, B., Davis, M.E., Eisen, E.A., Smith, T.J., 2008. Lung cancer and vehicle exhaust in trucking industry workers. *Environ. Health Perspect.* 116, 1327–1332. doi:10.1289/ehp.11293
- Gereffi, G., 2001. Beyond the producer-driven/buyer-driven dichotomy: The evolution of global value chains in the internet era. *IDS Bull.* 32, 30–40. doi:10.1111/j.1759-5436.2001.mp32003004.x
- Gimeno-García, E., Andreu, V., Boluda, R., 1996. Heavy metals incidence in the application of inorganic fertilizers and pesticides to rice farming soils. *Environ. Pollut.* 92, 19–25.

- Giskes, K., van Lenthe, F., Avendano-Pabon, M., Brug, J., 2011. A systematic review of environmental factors and obesogenic dietary intakes among adults: Are we getting closer to understanding obesogenic environments? *Obes. Rev. Off. J. Int. Assoc. Study Obes.* 12, e95–e106. doi:10.1111/j.1467-789X.2010.00769.x
- Gleeson, D., 2001. Health and safety in the catering industry. *Occup. Med.* 51, 385–391. doi:10.1093/occmed/51.6.385
- GLOPAN, 2016. Food systems and diets: Facing the challenges of the 21st century. Global Panel on Agriculture and Food Systems for Nutrition, London.
- Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., Toulmin, C., 2010. Food security: The challenge of feeding 9 billion people. *Science.* 327, 812–818. doi:10.1126/science.1185383
- Goldberg, J.P., Hellwig, J.P., 1997. Nutrition research in the media: The challenge facing scientists. *J. Am. Coll. Nutr.* 16, 544–550. doi:10.1080/07315724.1997.10718718
- Goldcamp, M., Hendricks, K.J., Myers, J.R., 2004. Farm fatalities to youth 1995–2000: A comparison by age groups. *J. Safety Res.* 35, 151–157. doi:10.1016/j.jsr.2003.11.005
- Golder, S., Loke, Y.K., 2008. Is there evidence for biased reporting of published adverse effects data in pharmaceutical industry-funded studies? *Br. J. Clin. Pharmacol.* 66, 767–773. doi:10.1111/j.1365-2125.2008.03272.x
- Goodwin, R., Schley, D., Lai, K., Ceddia, G.M., Barnett, J., Cook, N., 2012. Interdisciplinary approaches to zoonotic disease. *Infect. Dis. Rep.* 4, 146–151. doi:10.4081/idr.2012.e37
- Gore, A.C., Chappell, V.A., Fenton, S.E., Flaws, J.A., Nadal, A., Prins, G.S., Toppari, J., Zoeller, R.T., 2015. Executive summary to EDC-2: The Endocrine society's second scientific statement on endocrine-disrupting chemicals. *Endocr. Rev.* 36, 593–602. doi:10.1210/er.2015-1093
- Gould, L.H., Rosenblum, I., Nicholas, D., Phan, Q., Jones, T.F., 2015. Contributing factors in restaurant-associated foodborne disease outbreaks, FoodNet Sites, 2006 and 2007. *J. Food Prot.* 76, 1824–1828. doi:10.4315/0362-028X.JFP-13-037.
- Graeb, B.E., Chappell, M.J., Wittman, H., Ledermann, S., Kerr, R.B., Gemmill-Herren, B., 2016. The State of Family Farms in the World. *World Dev.* 87, 1–15. doi:10.1016/j.worlddev.2015.05.012
- Graham, J.P., Leibler, J.H., Price, L.B., Otte, J.M., Pfeiffer, D.U., Tiensin, T., Silbergeld, E.K., 2008. The animal-human interface and infectious disease in industrial food animal production: Rethinking biosecurity and biocontainment. *Public Health Rep.* 123, 282–299.
- Green, R., Sutherland, J., Dangour, A.D., Shankar, B., Webb, P., 2016. Global dietary quality, undernutrition and non-communicable disease: A longitudinal modelling study. *BMJ Open* 6, e009331. doi:10.1136/bmjopen-2015-009331
- Gregoire, A., 2002. The mental health of farmers. *Occup. Med. Oxf. Engl.* 52, 471–476.
- Grzywacz, J.G., Arcury, T.A., Marin, A., Carrillo, L., Coates, M.L., Burke, B., Quandt, S.A., 2007. The organization of work: Implications for injury and illness among immigrant latino poultry-processing workers. *Arch. Environ. Occup. Health.* 62, 19–26. doi:10.3200/AEOH.62.1.19-26
- Gu, B., Sutton, M.A., Chang, S.X., Ge, Y., Chang, J., 2014. Agricultural ammonia emissions contribute to China's urban air pollution. *Front. Ecol. Environ.* 12, 265–266. doi:10.1890/14.WB.007
- Gunnell, D., Eddleston, M., Phillips, M.R., Konradsen, F., 2007. The global distribution of fatal pesticide self-poisoning: Systematic review. *BMC Public Health.* 7, 357. doi:10.1186/1471-2458-7-357
- Gupta, S.K., Gupta, R.C., Chhabra, S.K., Eskiocak, S., Gupta, A.B., Gupta, R., 2008. Health issues related to N pollution in water and air. *ResearchGate.* 94.
- Habib, R.R., Fathallah, F.A., 2012. Migrant women farm workers in the occupational health literature. *Work Read. Mass* 41 Suppl 1, 4356–4362. doi:10.3233/WOR-2012-0101-4356
- Hamilton, A., 2016. *Got Milked?: What You Don't Know About Dairy and the Truth About Calcium*, Reprint edition. ed. New York: William Morrow Paperbacks.
- Hanselman, T.A., Graetz, D.A., Wilkie, A.C., 2003. Manure-borne estrogens as potential environmental contaminants: A review. *Environ. Sci. Technol.* 37, 5471–5478. doi:10.1021/es034410+

- Hansen, E., Donohoe, M., 2003. Health issues of migrant and seasonal farmworkers. *J. Health Care Poor Underserved*. 14, 153–164.
- Harrington, L., 2006. Warehousing: The safety zone [WWW Document]. *Inbound Logist*. URL <http://www.inboundlogistics.com/cms/article/warehousing-the-safety-zone/> (accessed 11.9.16).
- Harvard School of Public Health, 2012. Healthy eating plate & healthy eating pyramid [WWW Document]. *Nutr. Source*. URL <https://www.hsph.harvard.edu/nutritionsource/healthy-eating-plate/> (accessed 5.5.17).
- Harvest Help, 2012. Causes of food insecurity in African and other Third World countries [WWW Document]. Harvest Help — Afr. Food Issues. URL <http://www.harvesthelp.org.uk/causes-of-food-insecurity-in-african-and-other-third-world-countries.html>
- Haspel, T., 2014. Unearthed: Are patents the problem? *Wash. Post*.
- Heblich, S., Trew, A., Zylberberg, Y., 2016. East side story: Historical pollution and persistent neighborhood sorting. *Sch. Econ. Finance Discuss. Pap. No 1613 Univ. St Andrews*.
- Heiss, S.N., 2013. “Healthy” discussions about risk: The Corn Refiners Association’s strategic negotiation of authority in the debate over high fructose corn syrup. *Public Underst. Sci. Bristol Engl.* 22, 219–235. doi:10.1177/0963662511402281
- Hill, A.B., 1965. The Environment and Disease: Association or Causation? *Proc. R. Soc. Med.* 58, 295–300.
- Hoek, J., 2015. Informed choice and the nanny state: Learning from the tobacco industry. *Public Health*. 129, 1038–1045. doi:10.1016/j.puhe.2015.03.009
- Hoffmann, S., Batz, M.B., Morris, J.G., 2012. Annual cost of illness and quality-adjusted life year losses in the United States due to 14 foodborne pathogens. *J. Food Prot.* 75, 1292–1302. doi:10.4315/0362-028X.JFP-11-417
- Hoffmann, W., Terschüeren, C., Heimpel, H., Feller, A., Butte, W., Hostrup, O., Richardson, D., Greiser, E., 2008. Population-based research on occupational and environmental factors for leukemia and non-Hodgkin’s lymphoma: The Northern Germany Leukemia and Lymphoma Study (NLL). *Am. J. Ind. Med.* 51, 246–257. doi:10.1002/ajim.20551
- Hu, F.B., Malik, V.S., 2010. Sugar-sweetened beverages and risk of obesity and type 2 diabetes: Epidemiologic evidence. *Physiol. Behav., Beverages and Health*. 100, 47–54. doi:10.1016/j.physbeh.2010.01.036
- Huss, H.H., Reilly, A., Karim Ben Embarek, P., 2000. Prevention and control of hazards in sea-food. *Food Control*. 11, 149–156. doi:10.1016/S0956-7135(99)00087-0
- IARC, 1994. Acrylamide. *Int. Agency Res. Cancer IARC — Summ. Eval.* 60, 389.
- IARC/WHO, 2015. IARC Monographs Evaluate Consumption of Red Meat And Processed Meat. International Agency for Research on Cancer of the World Health Organization, Geneva.
- Iavicoli, I., Fontana, L., Bergamaschi, A., 2009. The effects of metals as endocrine disruptors. *J. Toxicol. Environ. Health B Crit. Rev.* 12, 206–223. doi:10.1080/10937400902902062
- IDF, 2016. IDF Diabetes Atlas, 7th Edition. International Diabetes Federation.
- IFPRI, 2016. Global Nutrition Report 2016: From Promise to Impact: Ending Malnutrition by 2030. International Food Policy Research Institute, Washington, DC.
- ILO, 2015. Giving a Voice to Rural Workers. ILC.104/III/1B. International Labour Office, Geneva.
- ILO, 2009. Agriculture: A hazardous work [WWW Document]. *Int. Labor Organ.* URL http://www.ilo.org/safework/areasofwork/hazardous-work/WCMS_110188/lang--en/index.htm (accessed 1.6.17).
- ILRI, ZSL Living Conservation, Hanoi School of Public Health, 2012. Mapping of poverty and likely zoonoses hotspots. *Zoonoses Proj. 4 Rep. Dep. Int. Dev. UK* 1–119.
- Ioannidis, J.P.A., 2016. Exposure-wide epidemiology: Revisiting Bradford Hill. *Stat. Med.* 35, 1749–1762. doi:10.1002/sim.6825
- Iowa Environmental Council, 2016. Nitrate in Drinking Water: A Public Health Concern for All Iowans. Iowa Environmental Council, Des Moines.
- IPES-Food, 2016. From uniformity to diversity: A paradigm shift from industrial agriculture to diversified agroecological systems. International Panel of Experts on Sustainable Food

Systems, Brussels.

- Jackson, H., Ormerod, P., 2017. Was Michael Gove right? Have we had enough of experts? [WWW Document]. *Prospect Mag*. URL <https://www.prospectmagazine.co.uk/magazine/michael-gove-right-about-experts-not-trust-them-academics-peer-review> (accessed 8.18.17).
- Jaenicke, H., Virchow, D., 2013. Entry points into a nutrition-sensitive agriculture. *Food Secur.* 5, 679–692. doi:10.1007/s12571-013-0293-5
- Jaffe, J., Gertler, M., 2006. Victual Vicissitudes: Consumer deskillling and the (gendered) transformation of food systems. *Agric. Hum. Values.* 23, 143–162. doi:10.1007/s10460-005-6098-1
- Jarrell, J., Gocmen, A., Foster, W., Brant, R., Chan, S., Sevcik, M., 1998. Evaluation of reproductive outcomes in women inadvertently exposed to hexachlorobenzene in southeastern Turkey in the 1950s. *Reprod. Toxicol.* Elmsford N 12, 469–476.
- Jenner, A., 2014. Chicken Farming and Its Discontents [WWW Document]. *Mod. Farmer*. URL <http://modernfarmer.com/2014/02/chicken-farming-discontents/> (accessed 11.2.16).
- Jensen, J.D., 2008. Scientific uncertainty in news coverage of cancer research: Effects of hedging on scientists' and journalists' credibility. *Hum. Commun. Res.* 34, 347–369. doi:10.1111/j.1468-2958.2008.00324.x
- Jensen, O.C.C., Petursdottir, G., Holmen, I.M., Abrahamsen, A., Lincoln, J., 2014. A review of fatal accident incidence rate trends in fishing. *Int. Marit. Health.* 65, 47–52. doi:10.5603/IMH.2014.0011
- Jiang, P., 2014. A uniform precautionary principle under EU law. *Peking Univ. Transnatl. Law Rev.* 2, 490.
- Jones, B.A., Grace, D., Kock, R., Alonso, S., Rushton, J., Said, M.Y., 2013. Zoonosis emergence linked to agricultural intensification and environmental change. *PNAS* 110, 8399–8404. doi:10.1073/pnas.1208059110
- Jones, C.S., Bleeker, J., 2005. A Comparison of ATV-related behaviors, exposures, and injuries between farm youth and nonfarm youth. *J. Rural Health.* 21, 70–73. doi:10.1111/j.1748-0361.2005.tb00064.x
- Kaewboonchoo, O., Kongtip, P., Woskie, S., 2015. Occupational health and safety for agricultural workers in Thailand: Gaps and recommendations, with a focus on pesticide use. *New Solut. J. Environ. Occup. Health Policy.* 25, 102–120. doi:10.1177/1048291115569028
- Kaminski, M., Bourguine, M., Zins, M., Touranchet, A., Verger, C., 1997. Risk factors for Raynaud's phenomenon among workers in poultry slaughterhouses and canning factories. *Int. J. Epidemiol.* 26, 371–380.
- Kaveeshwar, S.A., Cornwall, J., 2014. The current state of diabetes mellitus in India. *Australas. Med. J.* 7, 45–48. doi:10.4066/AMJ.2013.1979
- Kearns, C.E., Schmidt, L.A., Glantz, S.A., 2016. Sugar industry and coronary heart disease research: A historical analysis of internal industry documents. *JAMA Intern. Med.* 176, 1680–1685. doi:10.1001/jamainternmed.2016.5394
- Khetan, S., 2014. *Endocrine Disruptors in the Environment*. New Jersey: John Wiley & Sons, Inc.
- King, J.L., Toole, A.A., Fuglie, K.O., 2012. The Complementary Roles of the Public and Private Sectors in U.S. Agricultural Research and Development. United States Department of Agriculture, Economic Research Service, Washington, D.C.
- Kirkpatrick, S.I., McIntyre, L., Potestio, M.L., 2010. Child hunger and long-term adverse consequences for health. *Arch. Pediatr. Adolesc. Med.* 164, 754–762. doi:10.1001/archpediatrics.2010.117
- Knez, M., Graham, R.D., 2013. The Impact of Micronutrient Deficiencies in Agricultural Soils and Crops on the Nutritional Health of Humans, in: Selinus, O. (Ed.), *Essentials of Medical Geology*, Revised Edition. Springer Netherlands, pp. 517–533.
- Kolodziej, E.P., Harter, T., Sedlak, D.L., 2004. Dairy Wastewater, Aquaculture, and Spawning Fish as Sources of Steroid Hormones in the Aquatic Environment. *Environ. Sci. Technol.* 38, 6377–6384. doi:10.1021/es049585d
- Kölves, K., Milner, A., McKay, K., De Leo, D., 2012. Suicide in rural and remote areas of Australia. Australian Institute for Suicide Research and Prevention, Mt Gravatt, Qld.

- Konradsen, F., van der Hoek, W., Cole, D.C., Hutchinson, G., Daisley, H., Singh, S., Eddleston, M., 2003. Reducing acute poisoning in developing countries: Options for restricting the availability of pesticides. *Toxicology*. 192, 249–261.
- Krieger, N., 1994. Epidemiology and the web of causation: Has anyone seen the spider? *Soc. Sci. Med.* 1982 39, 887–903.
- Kristensen, P., Andersen, A., Irgens, L.M., Laake, P., Bye, A.S., 1996. Incidence and risk factors of cancer among men and women in Norwegian agriculture. *Scand. J. Work. Environ. Health*. 22, 14–26.
- Kross, B.C., Burmeister, L.F., Ogilvie, L.K., Fuortes, L.J., Fu, C.M., 1996. Proportionate mortality study of golf course superintendents. *Am. J. Ind. Med.* 29, 501–506. doi:10.1002/(SICI)1097-0274(199605)29:5<501::AID-AJIM8>3.0.CO;2-O
- Kumar, S., 2004. Occupational exposure associated with reproductive dysfunction. *J. Occup. Health*. 46, 1–19.
- Kutner, M., 2014. Death on the Farm [WWW Document]. *Newsweek*. URL <http://www.newsweek.com/2014/04/18/death-farm-248127.html> (accessed 11.1.16).
- Lack, G., 2008. Epidemiologic risks for food allergy. *J. Allergy Clin. Immunol.* 121, 1331–1336. doi:10.1016/j.jaci.2008.04.032
- Laden, F., Hart, J.E., Smith, T.J., Davis, M.E., Garshick, E., 2007. Cause-specific mortality in the unionized U.S. trucking industry. *Environ. Health Perspect.* 115, 1192–1196. doi:10.1289/ehp.10027
- Lake, A., Townshend, T., 2006. Obesogenic environments: Exploring the built and food environments. *J. R. Soc. Promot. Health*. 126, 262–267. doi:10.1177/1466424006070487
- Lang, T., Barling, D., Caraher, M., 2001. Food, social policy and the environment: Towards a new model. *Soc. Policy Adm.* 35, 538–558. doi:10.1111/1467-9515.t01-1-00252
- Lari, S.Z., Khan, N.A., Gandhi, K.N., Meshram, T.S., Thacker, N.P., 2014. Comparison of pesticide residues in surface water and ground water of agriculture intensive areas. *J. Environ. Health Sci. Eng.* 12, 11. doi:10.1186/2052-336X-12-11
- Larsen, M.H., Dalmasso, M., Ingmer, H., Langsrud, S., Malakauskas, M., Mader, A., Moretro, T., Mozina, S., Rychli, K., Wagner, M., Wallace, R.J., Zentek, J., Jordan, K., 2014. Persistence of foodborne pathogens and their control in primary and secondary food production chains. *Food Control*. 44, 92–109. doi:10.1016/j.foodcont.2014.03.039
- Larson, N.I., Story, M., Eisenberg, M.E., Neumark-Sztainer, D., 2006. Food preparation and purchasing roles among adolescents: Associations with sociodemographic characteristics and diet quality. *J. Am. Diet. Assoc.* 106, 211–218. doi:10.1016/j.jada.2005.10.029
- Laxminarayan, R., Matsuoka, P., Pant, S., Brower, C., Røttingen, J.A., Klugman, K., Davies, S., 2016. Access to effective antimicrobials: A worldwide challenge. *The Lancet*. 387, 168–175. doi:10.1016/S0140-6736(15)00474-2
- Ledésert, B., Saurel-Cubizolles, M.J., Bourguine, M., Kaminski, M., Touranchet, A., Verger, C., 1994. Risk factors for high blood pressure among workers in French poultry slaughterhouses and canneries. *Eur. J. Epidemiol.* 10, 609–620.
- Lee, K. N., 1994. *Compass and Gyroscope: Integrating Science and Politics for the Environment*. Washington: Island Press.
- Lehnert, T., Sonntag, D., Konnopka, A., Riedel-Heller, S., König, H.-H., 2013. Economic costs of overweight and obesity. *Best Pract. Res. Clin. Endocrinol. Metab.* 27, 105–115. doi:10.1016/j.beem.2013.01.002
- Leibler, J.H., Otte, J., Roland-Holst, D., Pfeiffer, D.U., Magalhaes, R.S., Rushton, J., Graham, J.P., Silbergeld, E.K., 2009. Industrial food animal production and global health risks: Exploring the ecosystems and economics of avian influenza. *EcoHealth*. 6, 58–70. doi:10.1007/s10393-009-0226-0
- Lelieveld, J., Evans, J.S., Fnais, M., Giannadaki, D., Pozzer, A., 2015. The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature*. 525, 367–371. doi:10.1038/nature15371

- Lesser, L.I., 2009. Reducing potential bias in industry-funded nutrition research. *Am. J. Clin. Nutr.* 90, 699–700. doi:10.3945/ajcn.2009.28093
- Lesser, L.I., Ebbeling, C.B., Goozner, M., Wypij, D., Ludwig, D.S., 2007. Relationship between funding source and conclusion among nutrition-related scientific articles. *PLoS Med.* 4, e5. doi:10.1371/journal.pmed.0040005
- Lexchin, J., Bero, L.A., Djulbegovic, B., Clark, O., 2003. Pharmaceutical industry sponsorship and research outcome and quality: Systematic review. *BMJ.* 326, 1167–1170. doi:10.1136/bmj.326.7400.1167
- Li, D.-K., Zhou, Z., Miao, M., He, Y., Wang, J., Ferber, J., Herrinton, L.J., Gao, E., Yuan, W., 2011. Urine bisphenol-A (BPA) level in relation to semen quality. *Fertil. Steril.* 95, 625–630–4. doi:10.1016/j.fertnstert.2010.09.026
- Liebman, M., Pelican, S., Moore, S.A., Holmes, B., Wardlaw, M.K., Melcher, L.M., Liddil, A.C., Paul, L.C., Dunnagan, T., Haynes, G.W., 2003. Dietary intake, eating behavior, and physical activity-related determinants of high body mass index in rural communities in Wyoming, Montana, and Idaho. *Int. J. Obes. Relat. Metab. Disord. J. Int. Assoc. Study Obes.* 27, 684–692. doi:10.1038/sj.ijo.0802277
- Lindsay, S., Selvaraj, S., Macdonald, J.W., Godden, D.J., 2004. Injuries to Scottish farmers while tagging and clipping cattle: A cross-sectional survey. *Occup. Med. Oxf. Engl.* 54, 86–91.
- Little, D.C., Vermillion, J.M., Dikis, E.J., Little, R.J., Custer, M.D., Cooney, D.R., 2003. Life on the farm—children at risk. *J. Pediatr. Surg.* 38, 804–807. doi:10.1016/j.jpsu.2003.50171
- Liverani, M., Waage, J., Barnett, T., Pfeiffer, D., Rushton, J., Rudge, J., Loevinsohn, M., Scoones, I., Smith, R., Cooper, B., White, L., Goh, S., Horby, P., Wren, B., Gundogdu, O., Woods, A., Coker, R., 2014. Understanding and managing zoonotic risk in the new livestock industries. *Environ. Health Perspect.* 121, 873–877. doi:10.1289/ehp.1206001
- Lloyd, C., James, S., 2008. Too much pressure? Retailer power and occupational health and safety in the food processing industry. *Work Employ. Soc.* 22, 713–730. doi:10.1177/0950017008098366
- Lobstein, T., Baur, L., Uauy, R., 2004. Obesity in children and young people: A crisis in public health. *Obes. Rev.* 5, 4–85. doi:10.1111/j.1467-789X.2004.00133.x
- Loew, C., 2005. Letter to the Editor: Conflicts of Interest and Independent Data Analysis in Industry-Funded Studies. *JAMA.* 294, 2575–2576.
- Löfstedt, R., 2004. The Swing of the Regulatory Pendulum in Europe: From Precautionary Principle to (Regulatory) Impact Analysis. AEI-Brook. Jt. Cent. Regul. Stud. Working Paper 04-07.
- London, L., 2000. Alcohol consumption amongst South African farm workers: A challenge for post-apartheid health sector transformation. *Drug Alcohol Depend.* 59, 199–206. doi:10.1016/S0376-8716(99)00120-9
- Love, D.C., Davis, M.F., Bassett, A., Gunther, A., Nachman, K.E., 2011. Dose Imprecision and Resistance: Free-Choice Medicated Feeds in Industrial Food Animal Production in the United States. *Environ. Health Perspect.* 119, 279–283. doi:10.1289/ehp.1002625
- Lovelock, K., Lilley, R., McBride, D., Milosavljevic, S., Yates, H., Cryer, C., 2008. Occupational injury and disease in agriculture in North America, Europe and Australasia: A review of the literature [IPRU Report No. ORO77]. University of Otago.
- Lu, J.L., 2005. Risk factors to pesticide exposure and associated health symptoms among cut-flower farmers. *Int. J. Environ. Health Res.* 15, 161–169. doi:10.1080/09603120500105638
- Lu, Y., Song, S., Wang, R., Liu, Z., Meng, J., Sweetman, A.J., Jenkins, A., Ferrier, R.C., Li, H., Luo, W., Wang, T., 2015. Impacts of soil and water pollution on food safety and health risks in China. *Environ. Int.* 77, 5–15. doi:10.1016/j.envint.2014.12.010
- Ludwig, D.S., 2011. Technology, Diet, and the Burden of Chronic Disease. *JAMA.* 305, 1352–1353. doi:10.1001/jama.2011.380
- Luengo-Fernandez, R., Leal, J., Gray, A., Sullivan, R., 2013. Economic burden of cancer across the European Union: A population-based cost analysis. *Lancet Oncol.* 14, 1165–1174. doi:10.1016/S1470-2045(13)70442-X

- Lund, B.M., 2015. Microbiological Food Safety for Vulnerable People. *Int. J. Environ. Res. Public Health*. 12, 10117–10132. doi:10.3390/ijerph120810117
- Lunner Kolstrup, C., Kallioniemi, M., Lundqvist, P., Kymäläinen, H.-R., Stallones, L., Brumby, S., 2013. International perspectives on psychosocial working conditions, mental health, and stress of dairy farm operators. *J. Agromedicine*. 18, 244–255. doi:10.1080/1059924X.2013.796903
- Macdiarmid, J.I., Kyle, J., Horgan, G.W., Loe, J., Fyfe, C., Johnstone, A., McNeill, G., 2012. Sustainable diets for the future: Can we contribute to reducing greenhouse gas emissions by eating a healthy diet? *Am. J. Clin. Nutr.* 96, 632–639. doi:10.3945/ajcn.112.038729
- Magnuson, B., Munro, I., Abbot, P., Baldwin, N., Lopez-Garcia, R., Ly, K., McGirr, L., Roberts, A., Socolovsky, S., 2013. Review of the regulation and safety assessment of food substances in various countries and jurisdictions. *Food Addit. Contam. Part Chem. Anal. Control Expo. Risk Assess.* 30, 1147–1220. doi:10.1080/19440049.2013.795293
- Malik, V.S., Popkin, B.M., Bray, G.A., Després, J.-P., Hu, F.B., 2010. Sugar-sweetened beverages, obesity, type 2 diabetes and cardiovascular disease risk. *Circulation*. 121, 1356–1364. doi:10.1161/CIRCULATIONAHA.109.876185
- Malik, V.S., Schulze, M.B., Hu, F.B., 2006. Intake of sugar-sweetened beverages and weight gain: A systematic review. *Am. J. Clin. Nutr.* 84, 274–288.
- Manitz, J., Kneib, T., Schlather, M., Helbing, D., Brockmann, D., 2014. Origin detection during foodborne disease outbreaks: A case study of the 2011 EHEC/HUS outbreak in Germany. *PLoS Curr*. 4. doi:10.1371/currents.outbreaks.f3fdeb08c5b9de7c09ed9cbcef5f01f2
- Marlenga, B., Doty, B.C., Berg, R.L., Linneman, J.G., 2006. Evaluation of a policy to reduce youth tractor crashes on public roads. *Inj. Prev. J. Int. Soc. Child Adolesc. Inj. Prev.* 12, 46–51.
- Marshall, B.M., Levy, S.B., 2011. Food animals and antimicrobials: Impacts on human health. *Clin. Microbiol. Rev.* 24, 718–733. doi:10.1128/CMR.00002-11
- Matheson, C., Morrison, S., Murphy, E., Lawrie, T., Ritchie, L., Bond, C., 2001. The health of fishermen in the catching sector of the fishing industry: A gap analysis. *Occup. Med. Oxf. Engl.* 51, 305–311.
- Mattei, C., Vetter, I., Eisenblätter, A., Krock, B., Ebbecke, M., Desel, H., Zimmermann, K., 2014. Ciguatera fish poisoning: A first epidemic in Germany highlights an increasing risk for European countries. *Toxicol. Off. J. Int. Soc. Toxicology*. 91, 76–83. doi:10.1016/j.toxicol.2014.10.016
- Mattes, R.D., 2006. Beverages and positive energy balance: The menace is the medium. *Int. J. Obes.* 30, S60–S65. doi:10.1038/sj.ijo.0803494
- Mayer, C.E., Joyce, A., 2005. The Escalating Obesity Wars. *Wash. Post*. <http://www.washingtonpost.com/wp-dyn/content/article/2005/04/26/AR2005042601259.html>
- McCarthy, S.N., Robson, P.J., Livingstone, M.B.E., Kiely, M., Flynn, A., Cran, G.W., Gibney, M.J., 2006. Associations between daily food intake and excess adiposity in Irish adults: Towards the development of food-based dietary guidelines for reducing the prevalence of overweight and obesity. *Int. J. Obes.* 2005 30, 993–1002. doi:10.1038/sj.ijo.0803235
- McCluskey, J., Swinnen, J., 2011. The media and food-risk perceptions. *EMBO Rep.* 12, 624–629. doi:10.1038/embor.2011.118
- McCurdy, S.A., Farrar, J.A., Beaumont, J.J., Samuels, S.J., Green, R.S., Scott, L.C., Schenker, M.B., 2004. Nonfatal occupational injury among California farm operators. *J. Agric. Saf. Health*. 10, 103–119.
- McEachran, A.D., Blackwell, B.R., Hanson, J.D., Wooten, K.J., Mayer, G.D., Cox, S.B., Smith, P.N., 2015. Antibiotics, bacteria, and antibiotic resistance genes: Aerial transport from cattle feed yards via particulate matter. *Environ. Health Perspect.* 123, 337–343. doi:10.1289/ehp.1408555
- McGwin, G., 2010. Causation in Epidemiology. *Am. J. Ophthalmol.* 150, 599–601. doi:10.1016/j.ajo.2010.06.031
- McHugh, M.D., 2006. Fit or fat?: A review of the debate on deaths attributable to obesity. *Public Health Nurs.* Boston Mass. 23, 264–270. doi:10.1111/j.1525-1446.2006.230309.x

- McIntosh, W.L., Spies, E., Stone, D.M., Lokey, C.N., Trudeau, A.-R.T., Bartholow, B., 2016. Suicide Rates by Occupational Group — 17 States, 2012. *MMWR Morb. Mortal. Wkly. Rep.* 65, 641–645. doi:10.15585/mmwr.mm6525a1
- McIntyre, L., Williams, J.V.A., Lavorato, D.H., Patten, S., 2013. Depression and suicide ideation in late adolescence and early adulthood are an outcome of child hunger. *J. Affect. Disord.* 150, 123–129. doi:10.1016/j.jad.2012.11.029
- McKinsey Global Institute, 2014. *Overcoming Obesity: An Initial Economic Analysis.* McKinsey & Company.
- Meek, R.W., Vyas, H., Piddock, L.J.V., 2015. Nonmedical uses of antibiotics: Time to restrict their use? *PLoS Biol.* 13, e1002266. doi:10.1371/journal.pbio.1002266
- Meena, V.D., Dotaniya, M.L., Saha, J.K., Patra, A.K., 2015. Antibiotics and antibiotic resistant bacteria in wastewater: Impact on environment, soil microbial activity and human health. *Afr. J. Microbiol. Res.* 9, 965–978. doi:10.5897/AJMR2015.7195
- Meiers, S., Baerg, J., 2001. Farm accidents in children: Eleven years of experience. *J. Pediatr. Surg.* 36, 726–729. doi:10.1053/jpsu.2001.22946
- Mekonnen, M.M., Pahlow, M., Aldaya, M.M., Zarate, E., Hoekstra, A.Y., 2015. Sustainability, efficiency and equitability of water consumption and pollution in Latin America and the Caribbean. *Sustainability.* 7, 2086–2112. doi:10.3390/su7022086
- Mekonnen, Y., Agonafir, T., 2002. Effects of pesticide applications on respiratory health of Ethiopian farm workers. *Int. J. Occup. Environ. Health.* 8, 35–40. doi:10.1179/oeh.2002.8.1.35
- Melnik, B.C., 2012. Leucine signaling in the pathogenesis of type 2 diabetes and obesity. *World J. Diabetes.* 3, 38–53. doi:10.4239/wjcd.v3.i3.38
- Merhi, M., Raynal, H., Cahuzac, E., Vinson, F., Cravedi, J.P., Gamet-Payrastre, L., 2007. Occupational exposure to pesticides and risk of hematopoietic cancers: Meta-analysis of case-control studies. *Cancer Causes Control CCC.* 18, 1209–1226. doi:10.1007/s10552-007-9061-1
- Mikkonen, J., Raphael, D., 2010. *Social Determinants of Health: The Canadian Facts.* York University School of Health Policy and Management, Toronto.
- Millennium Ecosystem Assessment (Ed.), 2005. *Ecosystems and human well-being: synthesis.* Washington, D.C.: Island Press.
- Mills, P.K., Shah, P., 2014. Cancer incidence in California farm workers, 1988–2010. *Am. J. Ind. Med.* 57, 737–747. doi:10.1002/ajim.22338
- Milner, A., Spittal, M.J., Pirkis, J., LaMontagne, A.D., 2013. Suicide by occupation: Systematic review and meta-analysis. *Br. J. Psychiatry.* 203, 409–416. doi:10.1192/bjp.bp.113.128405
- Mink, P.J., Adami, H.-O., Trichopoulos, D., Britton, N.L., Mandel, J.S., 2008. Pesticides and prostate cancer: A review of epidemiologic studies with specific agricultural exposure information. *Eur. J. Cancer Prev. Off. J. Eur. Cancer Prev. Organ. ECP.* 17, 97–110. doi:10.1097/CEJ.0b013e3280145b4c
- Mitloehner, F.M., Calvo, M.S., 2008. Worker Health and Safety in Concentrated Animal Feeding Operations. *J. Agric. Saf. Health.* 14, 163–187. doi:10.13031/2013.24349
- Monteiro, C., Cannon, G., Levy, R.B., Claro, R., Moubarac, J.-C., 2012. Commentary. The Food System. Ultra-processing: The big issue for nutrition, disease, health, well-being. *World Nutr.* 3.
- Monteiro, C.A., 2010. The big issue is ultra-processing [Commentary]. *World Nutr.* 1, 237–69.
- Moodie, R., Stuckler, D., Monteiro, C., Sheron, N., Neal, B., Thamarangsi, T., Lincoln, P., Casswell, S., 2013. Profits and pandemics: Prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. *The Lancet.* 381, 670–679. doi:10.1016/S0140-6736(12)62089-3
- Moreira, P.V.L., Baraldi, L.G., Moubarac, J.-C., Monteiro, C.A., Newton, A., Capewell, S., O’Flaherty, M., 2015. Comparing different policy scenarios to reduce the consumption of ultra-processed foods in UK: Impact on cardiovascular disease mortality using a modelling approach. *PLoS ONE.* 10, e0118353. doi:10.1371/journal.pone.0118353
- Morenga, L.T., Mallard, S., Mann, J., 2013. Dietary sugars and body weight: Systematic review and meta-analyses of randomised controlled trials and cohort studies. *BMJ* 346, e7492. doi:10.1136/bmj.e7492

- Morris, J.G., 2011. How safe is our food? *Emerg. Infect. Dis.* 17, 126–128. doi:10.3201/eid1701101821
- Morse, S.S., 2004. Factors and determinants of disease emergence. *Rev. Sci. Tech. Int. Off. Epizoot.* 23, 443–451.
- Murphy, D., 2010. Farmers look for justice in the poultry industry: Met with fear, threats, intimidation and hope in Alabama [WWW Document]. *Food Democr. Now*. URL <http://www.fooddemocracynow.org/blog/2010/may/28/farmers-look-justice-poultry-industry-met-fear-thr/> (accessed 11.2.16).
- Muscio, A., Quaglione, D., Vallanti, G., 2013. Does government funding complement or substitute private research funding to universities? *Res. Policy*. 42, 63–75. doi:10.1016/j.respol.2012.04.010
- Nagler, R.H., 2014. Adverse outcomes associated with media exposure to contradictory nutrition messages. *J. Health Commun.* 19, 24–40. doi:10.1080/10810730.2013.798384
- Nanni, O., Falcini, F., Buiatti, E., Bucchi, L., Naldoni, M., Serra, P., Scarpi, E., Saragoni, L., Amadori, D., 1998. Multiple myeloma and work in agriculture: Results of a case-control study in Forlì, Italy. *Cancer Causes Control CCC*. 9, 277–283.
- National Research Council, 2015. A framework for assessing effects of the food system. National Academies Press.
- NCD-RisC, 2016. Trends in adult body-mass index in 200 countries from 1975 to 2014: A pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *The Lancet*. 387, 1377–1396. doi:10.1016/S0140-6736(16)30054-X
- NCHS, 2016. Health, United States, 2015. National Center for Health Statistics, Hyattsville.
- Neff, R. (Ed.), 2014. *Introduction to the US Food System: Public Health, Environment, and Equity*. Hoboken: Wiley.
- Neff, R., Lawrence, R.S., 2014. Food Systems, in: Neff, R. (Ed.), *Introduction to the US Food System: Public Health, Environment, and Equity*. Hoboken: Wiley.
- Neff, R.A., Palmer, A.M., McKenzie, S.E., Lawrence, R.S., 2009. Food systems and public health disparities. *J. Hunger Environ. Nutr.* 4, 282–314. doi:10.1080/19320240903337041
- Nelson, W.J., Lee, B.C., Gasperini, F.A., Hair, D.M., 2012. Meeting the challenge of feeding 9 billion people safely and securely. *J. Agromedicine*. 17, 347–350. doi:10.1080/1059924X.2012.726161
- Neltner, T.G., Kulkarni, N.R., Alger, H.M., Maffini, M.V., Bongard, E.D., Fortin, N.D., Olson, E.D., 2011. Navigating the U.S. food additive regulatory program. *Compr. Rev. Food Sci. Food Saf.* 10, 342–368. doi:10.1111/j.1541-4337.2011.00166.x
- Nenonen, N., Saarela, K.L., Takala, J., Kheng, L.G., Yong, E., Ling, L.S., Manickam, K., Hämäläinen, P., 2014. Global Estimates of Occupational Accidents and Work-related Illnesses 2014. Tampere University of Technology, Tampere, Finland.
- Nestle, M., 2016. Food industry funding of nutrition research: The relevance of history for current debates. *JAMA Intern. Med.* 176, 1685–1686. doi:10.1001/jamainternmed.2016.5400
- Nestle, M., 2013. *Food Politics: How the Food Industry Influences Nutrition and Health*. Berkeley: University of California Press.
- Nestle, M., 2003. The ironic politics of obesity. *Science*. 299, 781–781. doi:10.1126/science.299.5608.781
- New, J., 2017. Why is federal government data disappearing? [WWW Document]. The Hill. URL <http://thehill.com/blogs/pundits-blog/technology/320511-why-is-federal-government-data-disappearing> (accessed 8.15.17).
- Newbold, R.R., 2010. Impact of environmental endocrine disrupting chemicals on the development of obesity. *Horm. Athens Greece*. 9, 206–217.
- Newell, D.G., Koopmans, M., Verhoef, L., Duizer, E., Aidara-Kane, A., Sprong, H., Opsteegh, M., Langelaar, M., Threfall, J., Scheutz, F., Giessen, J. Van Der, Kruse, H., 2010. Food-borne diseases: The challenges of 20 years ago still persist while new ones continue to emerge. *Int. J. Food Microbiol.* 139, S3–S15. doi:10.1016/j.ijfoodmicro.2010.01.021

- Newman, K.L., Leon, J.S., Newman, L.S., 2015. Estimating occupational illness, injury, and mortality in food production in the United States: A farm-to-table analysis. *J. Occup. Environ. Med.* 57, 718–725. doi:10.1097/JOM.0000000000000476
- Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., Mullany, E.C., Biryukov, S., Abbafati, C., Abera, S.F., Abraham, J.P., Abu-Rmeileh, N.M.E., Achoki, T., AlBuhairan, F.S., Alemu, Z.A., Alfonso, R., Ali, M.K., Ali, R., Guzman, N.A., Ammar, W., Anvari, P., Banerjee, A., Barquera, S., Basu, S., Bennett, D.A., Bhutta, Z., Blore, J., Cabral, N., Nonato, I.C., Chang, J.-C., Chowdhury, R., Courville, K.J., Criqui, M.H., Cundiff, D.K., Dabhadkar, K.C., Dandona, L., Davis, A., Dayama, A., Dharmaratne, S.D., Ding, E.L., Durrani, A.M., Esteghamati, A., Farzadfar, F., Fay, D.F.J., Feigin, V.L., Flaxman, A., Forouzanfar, M.H., Goto, A., Green, M.A., Gupta, R., Hafezi-Nejad, N., Hankey, G.J., Harewood, H.C., Havmoeller, R., Hay, S., Hernandez, L., Husseini, A., Idrisov, B.T., Ikeda, N., Islami, F., Jahangir, E., Jassal, S.K., Jee, S.H., Jeffreys, M., Jonas, J.B., Kabagambe, E.K., Khalifa, S.E.A.H., Kengne, A.P., Khader, Y.S., Khang, Y.-H., Kim, D., Kimokoti, R.W., Kinge, J.M., Kokubo, Y., Kosen, S., Kwan, G., Lai, T., Leinsalu, M., Li, Y., Liang, X., Liu, S., Logroscino, G., Lotufo, P.A., Lu, Y., Ma, J., Mainoo, N.K., Mensah, G.A., Merriman, T.R., Mokdad, A.H., Moschandreas, J., Naghavi, M., Naheed, A., Nand, D., Narayan, K.M.V., Nelson, E.L., Neuhouser, M.L., Nisar, M.I., Ohkubo, T., Oti, S.O., Pedroza, A., Prabhakaran, D., Roy, N., Sampson, U., Seo, H., Sepanlou, S.G., Shibuya, K., Shiri, R., Shiue, I., Singh, G.M., Singh, J.A., Skirbekk, V., Stapelberg, N.J.C., Sturua, L., Sykes, B.L., Tobias, M., Tran, B.X., Trasande, L., Toyoshima, H., Vijver, S. van de, Vasankari, T.J., Veerman, J.L., Velasquez-Melendez, G., Vlassov, V.V., Vollset, S.E., Vos, T., Wang, C., Wang, X., Weiderpass, E., Werdecker, A., Wright, J.L., Yang, Y.C., Yatsuya, H., Yoon, J., Yoon, S.-J., Zhao, Y., Zhou, M., Zhu, S., Lopez, A.D., Murray, C.J.L., Gakidou, E., 2014. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: A systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*. 384, 766–781. doi:10.1016/S0140-6736(14)60460-8
- Niles, M., Esquivel, J., Ahuja, R., Mango, N., 2017. *Climate Change & Food Systems: Assessing Impacts and Opportunities*. Meridian Institute, Washington, D.C.
- NIOSH, 2012. *Fatal occupational injuries, total hours worked, and rates of fatal occupational injuries by selected worker characteristics, occupations, and industries, civilian workers, 2008*. National Institute for Occupational Safety and Health, Washington, D.C.
- Novak, P.J., Arnold, W.A., Blazer, V.S., Halden, R.U., Klaper, R.D., Kolpin, D.W., Kriebel, D., Love, N.G., Martinović-Weigelt, D., Patisaul, H.B., Snyder, S.A., Vom Saal, F.S., Weisbrod, A.V., Swackhamer, D.L., 2011. On the need for a national (U.S.) research program to elucidate the potential risks to human health and the environment posed by contaminants of emerging concern. *Environ. Sci. Technol.* 45, 3829–3830. doi:10.1021/es200744f
- O'Brien, K., Reams, J., Caspari, A., Dugmore, A., Faghihimani, M., Fazey, I., Hackmann, H., Manuel-Navarrete, D., Marks, J., Miller, R., Raivio, K., Romero-Lankao, P., Virji, H., Vogel, C., Winiwarter, V., 2013. You say you want a revolution? Transforming education and capacity-building in response to global change. *Environ. Sci. Policy*, Special Issue: Responding to the Challenges of our Unstable Earth (RESCUE) 28, 48–59. doi:10.1016/j.envsci.2012.11.011
- O'Connor, A., 2016. How the Sugar Industry Shifted Blame to Fat. *N.Y. Times*.
- OECD, 2014. *Obesity update*. Organisation for Economic Co-operation and Development, Paris.
- Oggioni, C., Cena, H., Wells, J.C.K., Lara, J., Celis-Morales, C., Siervo, M., 2015. Association between worldwide dietary and lifestyle patterns with total cholesterol concentrations and DALYs for infectious and cardiovascular diseases: An ecological analysis. *J. Epidemiol. Glob. Health.* 5, 315–325. doi:10.1016/j.jegh.2015.02.002
- Okike, K., Kocher, M.S., Mehlman, C.T., Bhandari, M., 2008. Industry-sponsored research. *Injury, Principles and Practice of Clinical Research* 39, 666–680. doi:10.1016/j.injury.2008.02.013
- Orlando, E.F., Kolok, A.S., Binzcik, G.A., Gates, J.L., Horton, M.K., Lambright, C.S., Gray, L.E., Soto, A.M., Guillette, L.J., 2004. Endocrine-disrupting effects of cattle feedlot effluent on an aquatic sentinel species, the fathead minnow. *Environ. Health Perspect.* 112, 353–358.

- Otero, G., Preibisch, K., 2010. Farmworker Health and Safety Challenges for British Columbia. Simon Fraser University.
- Painter, J.A., Hoekstra, R.M., Ayers, T., Tauxe, R.V., Braden, C.R., Angulo, F.J., Griffin, P.M., 2013. Attribution of Foodborne Illnesses, Hospitalizations, and Deaths to Food Commodities by Using Outbreak Data, United States, 1998-2008. *Emerg. Infect. Dis.* 19, 407-415.
- PAN Germany, 2012. Pesticides and health hazards: Facts and figures. Pestizid Aktions-Netzwerk e.V., Hamburg.
- PAN North America, 2016. Kids on the Frontline. How pesticides are undermining the health of rural children. Pesticide Action Network North America, Oakland.
- Parascandola, M., 2011. Causes, risks, and probabilities: Probabilistic concepts of causation in chronic disease epidemiology. *Prev. Med.* 53, 232-234. doi:10.1016/j.ypmed.2011.09.007
- Parris, K., 2011. Impact of agriculture on water pollution in OECD countries: Recent trends and future prospects. *Int. J. Water Resour. Dev.* 27, 33-52. doi:10.1080/07900627.2010.531898
- Patz, J., Daszak, P., Tabor, G.M., Aguirre, A.A., Pearl, M., Epstein, J., Wolfe, N.D., Kilpatrick, A.M., Fofopoulos, J., Molyneux, D., Bradley, D.J., 2004. Unhealthy landscapes: Policy recommendations on land use change and infectious disease emergence. *Environ. Health Perspect.* 112, 1092-1098. doi:10.1289/ehp.6877
- Paulot, F., Jacob, D.J., 2014. Hidden cost of U.S. agricultural exports: Particulate matter from ammonia emissions. *Environ. Sci. Technol.* 48, 903-908. doi:10.1021/es4034793
- Paulson, J.A., Zaoutis, T.E., 2015. Nontherapeutic use of antimicrobial agents in animal agriculture: Implications for pediatrics. *Am. Acad. Pediatr.* 136, 5-7. doi:10.1542/peds.2015-3630
- Pellechia, M.G., 1997. Trends in science coverage: A content analysis of three US newspapers. *Public Underst. Sci.* 6, 49-68. doi:10.1088/0963-6625/6/1/004
- Pereira, M.A., 2006. The possible role of sugar-sweetened beverages in obesity etiology: A review of the evidence. *Int. J. Obes.* 30, S28-S36. doi:10.1038/sj.ijo.0803489
- Perera, F.P., Rauh, V., Tsai, W.-Y., Kinney, P., Camann, D., Barr, D., Bernert, T., Garfinkel, R., Tu, Y.-H., Diaz, D., Dietrich, J., Whyatt, R.M., 2003. Effects of transplacental exposure to environmental pollutants on birth outcomes in a multiethnic population. *Environ. Health Perspect.* 111, 201-205.
- Perlis, R.H., Perlis, C.S., Wu, Y., Hwang, C., Joseph, M., Nierenberg, A.A., 2005. Industry sponsorship and financial conflict of interest in the reporting of clinical trials in psychiatry. *Am. J. Psychiatry.* 162, 1957-1960. doi:10.1176/appi.ajp.162.10.1957
- Pew Charitable Trusts, 2013. The Business of Broilers — Hidden Costs of Putting a Chicken on Every Grill. The Pew Charitable Trusts.
- Pew Commission, 2007. Putting Meat on the Table: Industrial Farm Animal Production in America. Pew Commission on Industrial Farm Animal Production.
- Pickett, W., Brison, R., Berg, R., Zentner, J., Linneman, J., Marlenga, B., 2005. Pediatric farm injuries involving non-working children injured by a farm work hazard: Five priorities for primary prevention. *Inj. Prev.* 11, 6-11. doi:10.1136/ip.2004.005769
- Piesse, J., Thirtle, C., 2010. Agricultural R&D, technology and productivity. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 365, 3035-3047. doi:10.1098/rstb.2010.0140
- Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowitz, A., D'Amore, M., 1992. Environmental and Economic Costs of Pesticide Use. *BioScience.* 42, 750-760. doi:10.2307/1311994
- Pires, S., Vieira, A.R., Perez Gutierrez, E., Hald, T., 2011. Attributing human foodborne illness to food sources and water in Latin America and the Caribbean using data from outbreak investigations. *Int. J. Food Microbiol.* 152, 129-138. doi:10.1016/j.ijfoodmicro.2011.04.018
- Pires, S., Vigre, H., Makela, P., Hald, T., 2010. Using outbreak data for source attribution of human salmonellosis and campylobacteriosis in Europe. *Foodborne Pathog. Dis.* 7.
- Pollack, A., 2009. Crop Scientists Say Biotechnology Seed Companies Are Thwarting Research. *N.Y. Times.* <http://www.nytimes.com/2009/02/20/business/20crop.html>
- Podgorski, J.E., Eqani, S.A.M.A.S., Khanam, T., Ullah, R., Shen, H. and Berg, M., 2017. Extensive

- arsenic contamination in high-pH unconfined aquifers in the Indus Valley. *Science Advances*, 3(8), p.e1700935.
- Popkin, B.M., Hawkes, C., 2016. Sweetening of the global diet, particularly beverages: Patterns, trends, and policy responses. *Lancet Diabetes Endocrinol.* 4, 174–186. doi:10.1016/S2213-8587(15)00419-2
- Pottern, L.M., Heineman, E.F., Olsen, J.H., Raffn, E., Blair, A., 1992. Multiple myeloma among Danish women: Employment history and workplace exposures. *Cancer Causes Control CCC.* 3, 427–432.
- Powell, D., Erdozain, M.S., Dodd, C., Morley, K., Costa, R.E., 2013. Audits and inspections are never enough: A critique to enhance food safety. *Food Control.* 30, 686–691. doi:10.1016/j.foodcont.2012.07.044
- Prescott, S.L., Pawankar, R., Allen, K.J., Campbell, D.E., Sinn, J.K., Fiocchi, A., Ebisawa, M., Sampson, H.A., Beyer, K., Lee, B.-W., 2013. A global survey of changing patterns of food allergy burden in children. *World Allergy Organ. J.* 6, 21. doi:10.1186/1939-4551-6-21
- Price, L.B., Graham, J.P., Lackey, L.G., Roess, A., Vailes, R., Silbergeld, E., 2007. Elevated risk of carrying gentamicin-resistant *Escherichia coli* among U.S. poultry workers. *Environ. Health Perspect.* 115, 1738–1742. doi:10.1289/ehp.10191
- Provost, D., Cantagrel, A., Lebailly, P., Jaffré, A., Loyant, V., Loiseau, H., Vital, A., Brochard, P., Baldi, I., 2007. Brain tumours and exposure to pesticides: A case-control study in southwestern France. *Occup. Environ. Med.* 64, 509–514. doi:10.1136/oem.2006.028100
- Prüss-Ustün, A., Vickers, C., Haefliger, P., Bertollini, R., 2011. Knowns and unknowns on burden of disease due to chemicals: A systematic review. *Environ. Health.* 10, 9. doi:10.1186/1476-069X-10-9
- Rahman, S., 2009. Whether crop diversification is a desired strategy for agricultural growth in Bangladesh? *Food Policy.* 34, 340–349. doi:10.1016/j.foodpol.2009.02.004
- Rautiainen, R.H., Reynolds, S.J., 2002. Mortality and morbidity in agriculture in the United States. *J. Agric. Saf. Health.* 8, 259–276.
- Roberts, R.R., Hota, B., Ahmad, I., Li, R.D.S., Foster, S.D., Abbasi, F., Schabowski, S., Kampe, L.M., Ciavarella, G.G., Supino, M., Naples, J., Cordell, R., Levy, S.B., Weinstein, R.A., 2009. Hospital and Societal Costs of Antimicrobial-Resistant Infections in a Chicago Teaching Hospital: Implications for Antibiotic Stewardship 60612, 1175–1184. doi:10.1086/605630
- Roberts, S.B., McCrory, M.A., Saltzman, E., 2002. The influence of dietary composition on energy intake and body weight. *J. Am. Coll. Nutr.* 21, 140S–145S.
- Rodvall, Y., Ahlbom, A., Spännare, B., Nise, G., 1996. Glioma and occupational exposure in Sweden: A case-control study. *Occup. Environ. Med.* 53, 526–532.
- Rosenman, K.D., Kalush, A., Reilly, M.J., Gardiner, J.C., Reeves, M., Luo, Z., 2006. How much work-related injury and illness is missed by the current national surveillance system? *J. Occup. Environ. Med.* 48, 357–365. doi:10.1097/01.jom.0000205864.81970.63
- Rothman, K.J., Evans, S., 2005. Extra scrutiny for industry funded trials. *BMJ.* 331, 1350–1351.
- Rowlands, M.-A., Gunnell, D., Harris, R., Vatten, L.J., Holly, J.M.P., Martin, R.M., 2009. Circulating insulin-like growth factor peptides and prostate cancer risk: A systematic review and meta-analysis. *Int. J. Cancer.* 124, 2416–2429. doi:10.1002/ijc.24202
- Roy, J.R., Chakraborty, S., Chakraborty, T.R., 2009. Estrogen-like endocrine disrupting chemicals affecting puberty in humans: A review. *Med. Sci. Monit. Int. Med. J. Exp. Clin. Res.* 15, RA137-145.
- Rtveladze, K., Marsh, T., Webber, L., Kilpi, F., Levy, D., Conde, W., McPherson, K., Brown, M., 2013. Health and Economic Burden of Obesity in Brazil. *PLoS ONE.* 8, e68785. doi:10.1371/journal.pone.0068785
- Safran Foer, J., 2010. *Eating Animals*. New York: Back Bay Books.
- Saguy, A.C., Almeling, R., 2008. Fat in the fire? Science, the news media, and the “obesity epidemic.” *Sociol. Forum.* 23, 53–83. doi:10.1111/j.1600-0838.2004.00399.x-i1
- Samanic, C.M., De Roos, A.J., Stewart, P.A., Rajaraman, P., Waters, M.A., Inskip, P.D., 2008. Occupational exposure to pesticides and risk of adult brain tumors. *Am. J. Epidemiol.* 167, 976–985. doi:10.1093/aje/kwm401

- Sanborn, M., Kerr, K.J., Sanin, L.H., Cole, D.C., Bassil, K.L., Vakil, C., 2007. Non-cancer health effects of pesticides: Systematic review and implications for family doctors. *Can. Fam. Physician Med. Fam. Can.* 53, 1712–1720.
- Savage, J., Johns, C.B., 2015. Food allergy: Epidemiology and natural history. *Immunol. Allergy Clin. North Am., Pediatric Allergy*. 35, 45–59. doi:10.1016/j.iac.2014.09.004
- Savitz, D.A., Arbuckle, T., Kaczor, D., Curtis, K.M., 1997. Male pesticide exposure and pregnancy outcome. *Am. J. Epidemiol.* 146, 1025–1036.
- Scallan, E., Griffin, P.M., Angulo, F.J., Tauxe, R.V., Hoekstra, R.M., 2011a. Foodborne illness acquired in the United States: Unspecified agents. *Emerg. Infect. Dis.* 17, 16–22. doi:10.3201/eid1701.P21101
- Scallan, E., Hoekstra, R.M., Angulo, F.J., Tauxe, R.V., Widdowson, M., Roy, S.L., Jones, J.L., Griffin, P.M., 2011b. Foodborne illness acquired in the United States: Major pathogens. *Emerg. Infect. Dis.* 17, 7–15. doi:10.3201/eid1701.P11101
- Schaible, U.E., Kaufmann, S.H.E., 2007. Malnutrition and infection: Complex mechanisms and global impacts. *PLoS Med.* 4, e115. doi:10.1371/journal.pmed.0040115
- Schenker, M., 2011. Migration and occupational health: Understanding the risks [WWW Document]. migrationpolicy.org. URL <http://www.migrationpolicy.org/article/migration-and-occupational-health-understanding-risks> (accessed 9.17.15).
- Scherr, S.J., McNeely, J.A., 2012. *Farming with Nature: The Science and Practice of Ecoagriculture*. Washington, D.C.: Island Press.
- Schreuder, R., De Visser, C., 2014. Report EIP-AGRI Focus Group Protein Crops. European Innovation Partnership, Brussels.
- Scollo, M., Lal, A., Hyland, A., Glantz, S., 2003. Review of the quality of studies on the economic effects of smoke-free policies on the hospitality industry. *Tob. Control.* 12, 13–20. doi:10.1136/tc.12.1.13
- Sen, A., 1983. Development: Which Way Now? *Econ. J.* 93.
- Sen, A., 1981. *Poverty and Famines: An Essay on Entitlement and Deprivation*. New York: Oxford University Press.
- Settimi, L., Masina, A., Andrión, A., Axelson, O., 2003. Prostate cancer and exposure to pesticides in agricultural settings. *Int. J. Cancer.* 104, 458–461. doi:10.1002/ijc.10955
- Sharma-Wagner, S., Chokkalingam, A.P., Malker, H.S., Stone, B.J., McLaughlin, J.K., Hsing, A.W., 2000. Occupation and prostate cancer risk in Sweden. *J. Occup. Environ. Med.* 42, 517–525.
- Shaw, J.E., Sicree, R.A., Zimmet, P.Z., 2010. Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Res. Clin. Pract.* 87, 4–14. doi:10.1016/j.diabetes.2009.10.007
- Shi, H., Magaye, R., Castranova, V., Zhao, J., 2013. Titanium dioxide nanoparticles: A review of current toxicological data. *Part. Fibre Toxicol.* 10, 15. doi:10.1186/1743-8977-10-15
- Sibbald, B., 2012. Farm-grown superbugs: While the world acts, Canada dawdles. *Can. Med. Assoc. J.* 184, 1553–1553. doi:10.1503/cmaj.120561
- Simon, M., 2015. Nutrition Scientists on the Take from Big Food: Has the American Society for Nutrition Lost All credibility? Eat Drink Politics. <http://www.eatdrinkpolitics.com/>.
- Simon, M., 2013. And Now a Word From Our Sponsors: Are America's Nutrition Professionals in the Pocket of Big Food? Eat Drink Politics. <http://www.eatdrinkpolitics.com/>.
- Skocaj, M., Filipic, M., Petkovic, J., Novak, S., 2011. Titanium dioxide in our everyday life: Is it safe? *Radiol. Oncol.* 45, 227–247. doi:10.2478/v10019-011-0037-0
- Slingenbergh, J., Gilbert, M., de Balogh, K., Wint, W., 2004. Ecological sources of zoonotic diseases. *Rev. Sci. Tech. Int. Off. Epizoot.* 23, 467–484. doi:10.20506/rst.23.2.1492
- Smith, L.P., Ng, S.W., Popkin, B.M., 2013. Trends in US home food preparation and consumption: Analysis of national nutrition surveys and time use studies from 1965–1966 to 2007–2008. *Nutr. J.* 12, 45. doi:10.1186/1475-2891-12-45
- Smith, R., 2005. Medical journals are an extension of the marketing arm of pharmaceutical companies. *PLoS Med.* 2. doi:10.1371/journal.pmed.0020138
- Solomon, C., Poole, J., Palmer, K.T., Coggon, D., 2007. Non-fatal occupational injuries in British agriculture. *Occup. Environ. Med.* 64, 150–154. doi:10.1136/oem.2005.024265

- Sonestedt, E., Øverby, N., Laaksonen, D., Birgisdottir, B.E., 2012. Does high sugar consumption exacerbate cardiometabolic risk factors and increase the risk of type 2 diabetes and cardiovascular disease? *Food Nutr. Res.* 56, 19104. doi:10.3402/fnr.v56i0.19104
- Sormunen, E., Remes, J., Hassi, J., Pienimäki, T., Rintamäki, H., 2009. Factors associated with self-estimated work ability and musculoskeletal symptoms among male and female workers in cooled food-processing facilities. *Ind. Health.* 47, 271–282. doi:10.2486/ind-health.47.271
- Sosnowska, S., Kostka, T., 2007. Incidence and nature of farm-related injuries among children aged 6–15 during a 10-year period in one region in Poland. *Cent. Eur. J. Public Health.* 15, 33–37.
- Soto, A.M., Calabro, J.M., Prechtel, N.V., Yau, A.Y., Orlando, E.F., Daxenberger, A., Kolok, A.S., Guillette, L.J., le Bizec, B., Lange, I.G., Sonnenschein, C., 2004. Androgenic and estrogenic activity in water bodies receiving cattle feedlot effluent in Eastern Nebraska, USA. *Environ. Health Perspect.* 112, 346–352.
- Spellberg, B., Hansen, G.R., Kar, A., Cordova, C.D., Price, L.B., Johnson, J.R., 2016. Antibiotic Resistance in Humans and Animals. National Academy of Medicine.
- Spinelli, J.J., Ng, C.H., Weber, J.-P., Connors, J.M., Gascoyne, R.D., Lai, A.S., Brooks-Wilson, A.R., Le, N.D., Berry, B.R., Gallagher, R.P., 2007. Organochlorines and risk of non-Hodgkin lymphoma. *Int. J. Cancer.* 121, 2767–2775. doi:10.1002/ijc.23005
- SPLC, 2010. Injustice on Our Plates. Southern Poverty Law Center.
- Sprince, N.L., Park, H., Zwerling, C., Lynch, C.F., Whitten, P.S., Thu, K., Burmeister, L.F., Gillette, P.P., Alavanja, M.C.R., 2003. Risk factors for animal-related injury among Iowa large-live-stock farmers: A case-control study nested in the Agricultural Health Study. *J. Rural Health Off. J. Am. Rural Health Assoc. Natl. Rural Health Care Assoc.* 19, 165–173.
- Steele, E.M., Baraldi, L.G., Louzada, M.L. da C., Moubarac, J.-C., Mozaffarian, D., Monteiro, C.A., 2016. Ultra-processed foods and added sugars in the US diet: Evidence from a nationally representative cross-sectional study. *BMJ Open* 6, e009892. doi:10.1136/bmjopen-2015-009892
- Stein, A.J., Qaim, M., 2007. The Human and Economic Cost of Hidden Hunger. *Food Nutr. Bull.* 28, 125–134. doi:10.1177/156482650702800201
- Stender, S., Astrup, A., Dyerberg, J., 2016. Artificial trans fat in popular foods in 2012 and in 2014: A market basket investigation in six European countries. *BMJ Open.* 6, e010673. doi:10.1136/bmjopen-2015-010673
- Strawn, L.K., Fortes, E.D., Bihn, E.A., Nightingale, K.K., Gröhn, Y.T., Worobo, R.W., 2013. Landscape and Meteorological Factors Affecting Prevalence of Three Food-Borne Pathogens in Fruit and Vegetable Farms. *Appl. Environ. Microbiol.* 79, 588–600. doi:10.1128/AEM.02491-12
- Stuckler, D., McKee, M., Ebrahim, S., Basu, S., 2012. Manufacturing epidemics: the role of global producers in increased consumption of unhealthy commodities including processed foods, alcohol, and tobacco. *PLoS Med.* 9, e1001235. doi:10.1371/journal.pmed.1001235
- Stutz, B., 2010. Companies Put Restrictions on Research into GM Crops [WWW Document]. Yale E360. URL http://e360.yale.edu/features/companies_put_restrictions_on_research_into_gm_crops (accessed 5.5.17).
- Sundström, J.F., Albiñ, A., Boqvist, S., Ljungvall, K., Marstorp, H., Martiin, C., Nyberg, K., Vågsholm, I., Yuen, J., Magnusson, U., 2014. Future threats to agricultural food production posed by environmental degradation, climate change, and animal and plant diseases: A risk analysis in three economic and climate settings. *Food Secur.* 6, 201–215. doi:10.1007/s12571-014-0331-y
- Swinburn, B., Egger, G., Raza, F., 1999. Dissecting obesogenic environments: The development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev. Med.* 29, 563–570. doi:10.1006/pmed.1999.0585
- Swinburn, B.A., Caterson, I., Seidell, J.C., James, W.P.T., 2004. Diet, nutrition and the prevention of excess weight gain and obesity. *Public Health Nutr.* 7, 123–146. doi:10.1079/PHN2003585

- Tarasuk, V., Cheng, J., de Oliveira, C., Dachner, N., Gundersen, C., Kurdyak, P., 2015. Association between household food insecurity and annual health care costs. *CMAJ Can. Med. Assoc. J. J. Assoc. Medicale Can.* 187, E429-436. doi:10.1503/cmaj.150234
- Tarasuk, V., Mitchell, A., McLaren, L., McIntyre, L., 2013. Chronic physical and mental health conditions among adults may increase vulnerability to household food insecurity. *J. Nutr.* 143, 1785–1793. doi:10.3945/jn.113.178483
- Taylor, A., Jacobson, M., 2016. Carbonating the world: The marketing and health impact of sugar drinks in low- and middle-income countries. Center for Science in the Public Interest.
- Thayer, K.A., Heindel, J.J., Bucher, J.R., Gallo, M.A., 2012. Role of environmental chemicals in diabetes and obesity: A National Toxicology Program workshop review. *Environ. Health Perspect.* 120, 779–789. doi:10.1289/ehp.1104597
- The PLoS Medicine Editors, 2012. PLoS Medicine Series on Big Food: The Food Industry Is Ripe for Scrutiny. *PLoS Med.* 9, e1001246. doi:10.1371/journal.pmed.1001246
- The PLoS Medicine Editors, 2008. Making Sense of Non-Financial Competing Interests. *PLoS Med.* 5, e199. doi:10.1371/journal.pmed.0050199
- Thornley, S., Tayler, R., Sikaris, K., 2012. Sugar restriction: The evidence for a drug-free intervention to reduce cardiovascular disease risk. *Intern. Med. J.* 42, 46–58. doi:10.1111/j.1445-5994.2012.02902.x
- Tilman, D., Clark, M., 2014. Global diets link environmental sustainability and human health. *Nature.* 515, 518–22.
- Toan, P.V., Sebesvari, Z., Bläsing, M., Rosendahl, I., Renaud, F.G., 2013. Pesticide management and their residues in sediments and surface and drinking water in the Mekong Delta, Vietnam. *Sci. Total Environ.* 452–453, 28–39. doi:10.1016/j.scitotenv.2013.02.026
- Trasande, L., Zoeller, R.T., Hass, U., Kortenkamp, A., Grandjean, P., Myers, J.P., DiGangi, J., Hunt, P.M., Rudel, R., Sathyanarayana, S., Bellanger, M., Hauser, R., Legler, J., Skakkebaek, N.E., Heindel, J.J., 2016. Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: An updated analysis. *Andrology.* 4, 565–572. doi:10.1111/andr.12178
- Tunncliffe, W.S., O’Hickey, S.P., Fletcher, T.J., Miles, J.F., Burge, P.S., Ayres, J.G., 1999. Pulmonary function and respiratory symptoms in a population of airport workers. *Occup. Environ. Med.* 56, 118–123.
- Turrall, H., 2012. Water pollution from agriculture: A review. Food and Agriculture Organization of the United Nations, Rome.
- United Farm Workers, 2017. Methyl Iodide [WWW Document]. United Farm Work. URL <http://ufw.org/methyl-iodide/>
- United Nations, 1992. Rio Declaration on Environment and Development 1992.
- USAID, 2015. Nutrition-Sensitive Agriculture: Nutrient-Rich Value Chains. US Agency for International Development, Washington, D.C.
- Valentine, K., 2015. Groups Sue EPA Over Failure to Regulate Emissions From Factory Farms [WWW Document]. ThinkProgress. URL <https://thinkprogress.org/groups-sue-epa-over-failure-to-regulate-emissions-from-factory-farms-17f48b40604c> (accessed 5.16.17).
- Van Maele-Fabry, G., Duhayon, S., Mertens, C., Lison, D., 2008. Risk of leukaemia among pesticide manufacturing workers: A review and meta-analysis of cohort studies. *Environ. Res.* 106, 121–137. doi:10.1016/j.envres.2007.09.002
- Van Wijngaarden, E., 2003. Mortality of mental disorders in relation to potential pesticide exposure. *J. Occup. Environ. Med.* 45, 564–568.
- Vanga, S.K., Singh, A., Raghavan, V., 2015. Review of conventional and novel food processing methods on food allergens. *Crit. Rev. Food Sci. Nutr.* doi:10.1016/j.future.2015.08.005
- Vartanian, L.R., Schwartz, M.B., Brownell, K.D., 2007. Effects of soft drink consumption on nutrition and health: A systematic review and meta-analysis. *Am. J. Public Health.* 97, 667–675. doi:10.2105/AJPH.2005.083782
- Verhoeckx, K.C.M., Vissers, Y.M., Baumert, J.L., Faludi, R., Feys, M., Flanagan, S., Herouet-Guicheney, C., Holzhauser, T., Shimojo, R., van der Bolt, N., Wichers, H., Kimber, I., 2015. Food processing and allergenicity. *Food Chem. Toxicol.* 80, 223–240. doi:10.1016/j.fct.2015.03.005

- Vermeulen, S.J., Campbell, B.M., Ingram, J.S.I., 2012. Climate change and food systems. *Annu. Rev. Environ. Resour.* 37, 195–222. doi:10.1146/annurev-environ-020411-130608
- Viel, J.F., Challier, B., Pitard, A., Pobel, D., 1998. Brain cancer mortality among French farmers: The vineyard pesticide hypothesis. *Arch. Environ. Health.* 53, 65–70. doi:10.1080/00039899809605690
- Viel, J.-F., Richardson, S.T., 1993. Lymphoma, multiple myeloma and leukaemia among French farmers in relation to pesticide exposure. *Soc. Sci. Med., Special Issue: The Scope of Medical Geography* 37, 771–777. doi:10.1016/0277-9536(93)90371-A
- Vieno, M., Heal, M.R., Twigg, M.M., MacKenzie, I.A., Braban, C.F., Lingard, J.J.N., Ritchie, S., Beck, R.C., Moring, A., R Ots, Marco, C.F.D., Nemitz, E., Sutton, M.A., Reis, S., 2016. The UK particulate matter air pollution episode of March–April 2014: More than Saharan dust. *Environ. Res. Lett.* 11, 44004. doi:10.1088/1748-9326/11/4/044004
- Villarejo, D., 2012. *Health-related Inequities Among Hired Farm Workers and the Resurgence of Labor-intensive Agriculture*. The Kresge Foundation, Troy, Michigan.
- Visciano, P., Schirone, M., Berti, M., Milandri, A., Tofalo, R., Suzzi, G., 2016. Marine biotoxins: Occurrence, toxicity, regulatory limits and reference methods. *Front. Microbiol.* 7. doi:10.3389/fmicb.2016.01051
- Von Schomberg, R., 2012. The precautionary principle: Its use within hard and soft law. *Eur. J. Risk Regul.* 2.
- Vozoris, N.T., Tarasuk, V.S., 2003. Household food insufficiency is associated with poorer health. *J. Nutr.* 133, 120–126.
- Wager, E., Mhaskar, R., Warburton, S., Djulbegovic, B., 2010. JAMA published fewer industry-funded studies after introducing a requirement for independent statistical analysis. *PLoS ONE.* 5, e13591. doi:10.1371/journal.pone.0013591
- Wallinga, D., 2009. Today's food system: How healthy is it? *J. Hunger Environ. Nutr.* 4, 251–281. doi:10.1080/19320240903336977
- Wang, Y., Beydoun, M.A., Liang, L., Caballero, B., Kumanyika, S.K., 2008. Will all Americans become overweight or obese? Estimating the progression and cost of the US obesity epidemic. *Obes. Silver Spring Md.* 16, 2323–2330. doi:10.1038/oby.2008.351
- Wang, Y.C., McPherson, K., Marsh, T., Gortmaker, S.L., Brown, M., 2011. Health and economic burden of the projected obesity trends in the USA and the UK. *The Lancet.* 378, 815–825. doi:10.1016/S0140-6736(11)60814-3
- Watts, N., Adger, W.N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., Chaytor, S., Colbourn, T., Collins, M., Cooper, A., Cox, P.M., Depledge, J., Drummond, P., Ekins, P., Galaz, V., Grace, D., Graham, H., Grubb, M., Haines, A., Hamilton, I., Hunter, A., Jiang, X., Li, M., Kelman, I., Liang, L., Lott, M., Lowe, R., Luo, Y., Mace, G., Maslin, M., Nilsson, M., Oreszczyn, T., Pye, S., Quinn, T., Svendsdotter, M., Venevsky, S., Warner, K., Xu, B., Yang, J., Yin, Y., Yu, C., Zhang, Q., Gong, P., Montgomery, H., Costello, A., 2015. Health and climate change: Policy responses to protect public health. *The Lancet.* 386, 1861–1914. doi:10.1016/S0140-6736(15)60854-6
- Weiser, S., Palar, K., Hatcher, A., Young, S., Frongillo, E., Laraia, B., 2015. Food Insecurity and Health: A Conceptual Framework, in: Ivers, L. (Ed.), *Food Insecurity and Public Health*. Boca Raton, FL: CRC Press, pp. 23–50. doi:10.1201/b18451-3
- WFP, 2015. A World with Zero Hunger Needs Resilience to Climate Change [WWW Document]. World Food Programme. URL http://documents.wfp.org/stellent/groups/public/documents/communications/wfp288236.pdf?_ga=1.216300118.1372559755.1484507439
- Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A.G., Dias, B.F. de S., Ezeh, A., Frumkin, H., Gong, P., Head, P., Horton, R., Mace, G.M., Marten, R., Myers, S.S., Nishtar, S., Osofsky, S.A., Pattanayak, S.K., Pongsiri, M.J., Romanelli, C., Soucat, A., Vega, J., Yach, D., 2015. Safeguarding human health in the Anthropocene epoch: Report of The Rockefeller Foundation–Lancet Commission on planetary health. *The Lancet.* 386, 1973–2028. doi:10.1016/S0140-6736(15)60901-1
- WHO, 2015a. WHO Estimates of the Global Burden of Foodborne Diseases. World Health Organ.
- WHO, 2015b. Sugars Intake for Adults and Children. Guideline. World Health Organization, Geneva.

- WHO, 2014. Global Status Report on Noncommunicable Diseases 2014. World Health Organization, Geneva.
- WHO, 2012. The evolving threat of antimicrobial resistance: Options for action. World Health Organization, Geneva.
- WHO/FAO, 2002. Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases. World Health Organization/Food and Agriculture Organization of the United Nations, Geneva.
- WHO/UNEP, 2013. State of the science of endocrine disrupting chemicals — 2012. An assessment of the state of the science of endocrine disruptors prepared by a group of experts for the United Nations Environment Programme (UNEP) and WHO. World Health Organization, Geneva.
- WHO/UNICEF/WBG, 2016. Levels and trends in child malnutrition. World Health Organization, Geneva.
- Wielogórska, E., Elliott, C.T., Danaher, M., Connolly, L., 2015. Endocrine disruptor activity of multiple environmental food chain contaminants. *Toxicol. In Vitro*. 29, 211–220. doi:10.1016/j.tiv.2014.10.014
- Wiener, J.B., Rogers, M.D., Hammitt, J.K., Sand, P.H., 2010. *The Reality of Precaution: Comparing Risk Regulation in the United States and Europe*, 1 edition. ed. Routledge, Washington, DC.
- Wilkinson, R., Pickett, K., 2010. *The Spirit Level: Why Equality is Better for Everyone*, New Edition. ed. Penguin, London.
- Wilson, K., Young, T.K., 2008. An overview of Aboriginal health research in the social sciences: Current trends and future directions. *Int. J. Circumpolar Health*. 67, 179–189.
- Windham, G., Fenster, L., 2008. Environmental contaminants and pregnancy outcomes. *Fertil. Steril.* 89, e111–116; discussion e117. doi:10.1016/j.fertnstert.2007.12.041
- Windle, M.J.S., Neis, B., Bornstein, S., Binkley, M., Navarro, P., 2008. Fishing occupational health and safety: A comparison of regulatory regimes and safety outcomes in six countries. *Mar. Policy*. 32, 701–710. doi:10.1016/j.marpol.2007.12.003
- Wolff, M.S., Engel, S., Berkowitz, G., Teitelbaum, S., Siskind, J., Barr, D.B., Wetmur, J., 2007. Prenatal pesticide and PCB exposures and birth outcomes. *Pediatr. Res.* 61, 243–250. doi:10.1203/pdr.0b013e31802d77f0
- World Cancer Research Fund/AICR, 2007. Food, Nutrition, Physical Activity, and the Prevention of Cancer: A Global Perspective. American Institute for Cancer Research, Washington, D.C.
- WTO, 2015. International Trade Statistics 2015. World Trade Organization, Geneva.
- Xu, Y., Cui, B., Ran, R., Liu, Y., Chen, H., Kai, G., Shi, J., 2014. Risk assessment, formation, and mitigation of dietary acrylamide: Current status and future prospects. *Food Chem. Toxicol.* 69, 1–12. doi:10.1016/j.fct.2014.03.037
- Yadav, I.C., Devi, N.L., Syed, J.H., Cheng, Z., Li, J., Zhang, G., Jones, K.C., 2015. Current status of persistent organic pesticides residues in air, water, and soil, and their possible effect on neighboring countries: A comprehensive review of India. *Sci. Total Environ.* 511, 123–137. doi:10.1016/j.scitotenv.2014.12.041
- Yang, Q., Zhang, Z., Gregg, E.W., Flanders, W.D., Merritt, R., Hu, F.B., 2014. Added sugar intake and cardiovascular diseases mortality among US adults. *JAMA Intern. Med.* 174, 516–524. doi:10.1001/jamainternmed.2013.13563
- Yeni, F., Yavas, S., Alpas, H., Soyer, Y., 2016. Most common foodborne pathogens and mycotoxins on fresh produce: A review of recent outbreaks. *Crit. Rev. Food Sci. Nutr.* 56, 1532–1544. doi:10.1080/10408398.2013.777021
- Ying, G.-G., Williams, B., Kookana, R., 2002. Environmental fate of alkylphenols and alkylphenol ethoxylates: A review. *Environ. Int.* 28, 215–226. doi:10.1016/S0160-4120(02)00017-X
- You, Y., Hilpert, M., Ward, M.J., 2012. Detection of a common and persistent tet(L)-carrying plasmid in chicken-waste-impacted farm soil. *Appl. Environ. Microbiol.* 78, 3203–3213. doi:10.1128/AEM.07763-11
- Zhang, P., Zhang, X., Brown, J., Vistisen, D., Sicree, R., Shaw, J., Nichols, G., 2010. Global healthcare expenditure on diabetes for 2010 and 2030. *Diabetes Res. Clin. Pract.* 87, 293–301. doi:10.1016/j.diabres.2010.01.026

- Zhang, X.Y., Ding, L.J., Yue, J., 2009. Occurrence and characteristics of class 1 and class 2 integrons in resistant *Escherichia coli* isolates from animals and farm workers in northeastern China. *Microb. Drug Resist. Larchmt.* N 15, 323–328. doi:10.1089/mdr.2009.0020
- Zhang, Y., Ma, B., Fan, Q., 2010. Mechanisms of breast cancer bone metastasis. *Cancer Lett.* 292, 1–7. doi:10.1016/j.canlet.2009.11.003
- Ziska, L., Crimmins, A., Auclair, A., DeGrasse, S., Garofalo, J.F., Khan, A.S., Loladze, I., Pérez de León, A.A., Showler, A., Thurston, J., Walls, I., 2016. Ch. 7: Food Safety, Nutrition, and Distribution, in: *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. U.S. Global Change Research Program, Washington, D.C., pp. 189–216.

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