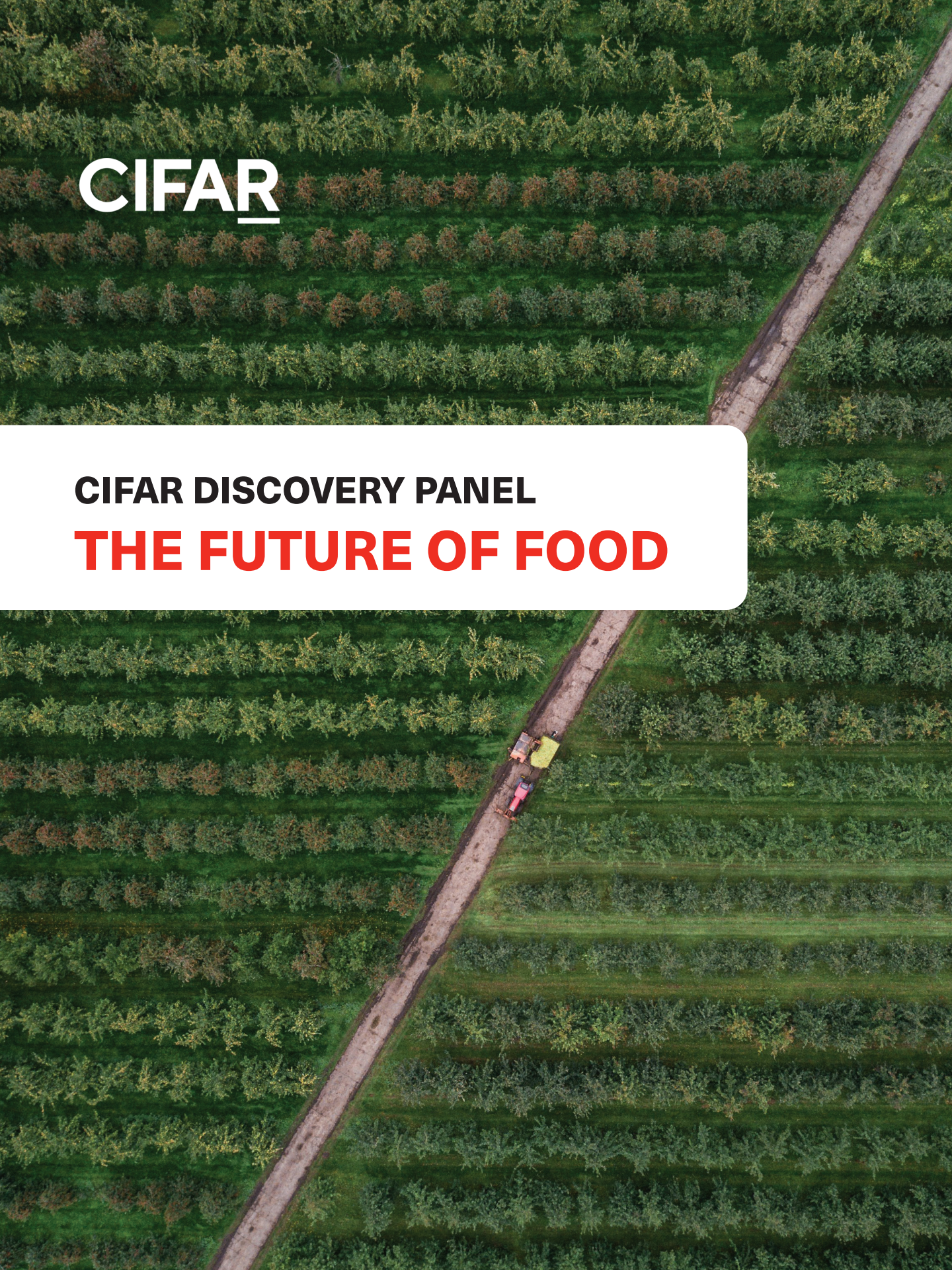

CIFAR

CIFAR DISCOVERY PANEL

THE FUTURE OF FOOD

THE ARRELL FAMILY

FOUNDATION

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In 2024, CIFAR brought together nine international, interdisciplinary experts to explore the complex challenges related to the Future of Food. This report provides an overview of their discussions and recommendations to CIFAR for potentially transformative future areas of research.

BACKGROUND

How we produce, transport, trade, consume, and dispose of food is entwined with public policy, health, economics, environment, behaviours and culture. Food, and what it will look like in the future, is foundational to human and planetary health and is at the heart of multiple high-level systems, from climate change and the environment to agriculture and ocean economies, to food security and sovereignty. Across the globe food insecurity is rising, and climate change is intensifying, becoming more unpredictable. The Sustainable Development Goal #2, Zero Hunger, shows the most regression among all Sustainable Development Goals.[1] Declining biodiversity is impacting traditional agricultural lands and driving rapid change in urban food systems. Pathogens are spreading and evolving, presenting new risks to crops and livestock. The issues facing the global food system are of urgent concern today and growing in importance and complexity, making them critical to our future.

Food — its production, transportation and processing — is responsible for the greatest impact humans have on this planet; using 50% of habitable land and accounting for 70% of freshwater use, it produces a third of all anthropogenic greenhouse gas emissions. Considering deforestation, soil degradation, and use of water and fossil fuels, it dwarfs all other human activities in terms of transforming the planet.

In May and June 2024, CIFAR held virtual meetings with the Discovery Panel on the Future of Food to set the stage for an in-person meeting in July. Deborah Buszard (University of British Columbia) was invited to chair the panel, and was joined by Kyle Bobiwash (University of Manitoba), Simon Bush (Wageningen University), Hugo Campos (International Potato Center), Mariaelena Huambachano (Syracuse University), Peter Phillips (University of Saskatchewan), Alon Shepon (Tel Aviv University), Éliane Ubalijoro (CIFOR-ICRAF), and Anna Zeide (Virginia Tech).

CIFAR MODEL

There is a strong prima facie case to be made for the value of investment in research to support the global food system. This includes agricultural ecosystems, the land-based economy (both agriculture and forestry), food security and distribution, the new blue economy, and research to address climate change. At the same time, research is needed to move agriculture toward being nature positive and carbon neutral — rather than contributing to greenhouse gas emissions, using half the world's habitable land surface, and contributing significantly to biodiversity loss.[2]

1 United Nations. *The Sustainable Development Goals Report 2024*. https://unstats.un.org/sdgs/report/2024/The-Sustainable-Development-Goals-Report-2024.pdf.

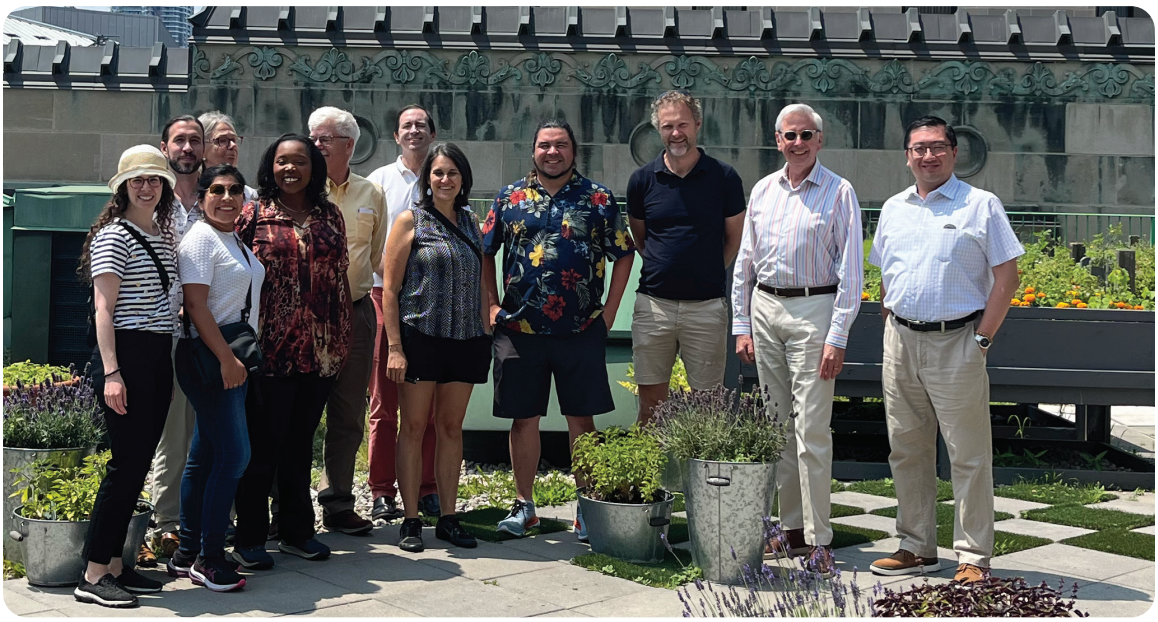
2 IPCC, 2023: Summary for Policymakers. In: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, p. 5.

In addition, a better understanding of the history, sociology, anthropology, and diverse cultures of food and how they can inform current food processes, play a role in shaping public policy, actions of the private sector and consumers may allow for more successful evolution of food systems. Many international agencies, charities, and non-profit organizations aim to tackle aspects of the food system — from poverty and food security, addressing immediate needs in areas faced with war or drought — to seeking solutions to broad questions around trade, governance and production of food.

However, advances in research, like agriculture, can take time, and the CIFAR model aims to support fundamental research by bringing together leading researchers from across disciplines and geographies to work on complex, long-term problems. CIFAR's model is designed to bridge disciplinary divides, identify new avenues of inquiry and create transformative knowledge. CIFAR aims to examine challenges on the horizon: areas of research that are likely to increase dramatically in importance; are unlikely to be resolved through incremental improvements; have significant implications for humanity's collective well-being and welfare; and are not currently the target of major investment by others.

For over 40 years, CIFAR has asked deep questions, bringing together long-term international, interdisciplinary research networks to support areas of research at the cutting edge, focussed on the future. For example, CIFAR's consistent commitment to building the field of Artificial Intelligence has paid off to an extraordinary degree. The Discovery Panel on the Future of Food was asked to use this framework and definitions of an "horizon challenge, to identify early signals of and opportunities for change." CIFAR's methods of working seem ideally suited to address the complex global challenges and opportunities which will define the Future of Food — from reducing the environmental impacts of food production to increasing plant-based and other options to meet the world's growing protein demands to addressing the crisis of food waste and combatting biodiversity loss.

The CIFAR model offers the opportunity to focus on more speculative, but potentially high-reward, high-impact research that is unconstrained by a need to prove immediate application, while being highly attentive to potential impact. Combined with diverse groups of exceptional minds, this focus creates an extraordinary opportunity for new ideas, insights and knowledge that can reshape fields and enable exciting new possibilities for humanity. The Future of Food Discovery Panel was convened as part of CIFAR's Foresight and Discovery initiatives, in order to identify research opportunities that are as forward-looking and high-potential as possible.



Members of the Discovery Panel on the Future of Food at the Royal York Hotel's rooftop garden.

Photo: Jacqui Sullivan

CRITICAL INFLUENCES ON THE FOOD SYSTEM

Food systems are complex and operate on a global scale. Historically, people mainly ate food they grew or sourced from local producers using traditional methods.[3] Today, however, most consumers obtain a considerable portion of their daily protein, fiber, and micronutrients from food produced and processed by others, often in distant regions, using a diversity of production techniques. This has had significant influence over food production, consumption, transportation, governance, and trade, deepening the food system's impact on individuals, society, and the planet. The panel attempted to identify the critical components of this complex global system that would benefit from investment toward fundamental understanding and offer opportunities for real impact on the future of food.

Food security is no longer primarily a local problem of less developed nations in what we often call the Global South, but rather a collective challenge for an estimated 1.3 billion producers and a dynamic and increasingly interconnected set of input providers and down-stream supply chain integrators, manufacturers, wholesalers, and retailers. Even highly developed countries currently face food insecurity for segments of their populations. Governance and regulatory frameworks embedded at local, regional, and global levels are increasingly interdependent. From concepts such as food sovereignty to food system resilience, given the complexity of the global food system, future solutions will need to address constraints across scales to provide economically viable, equitable, nutritious, and environmentally sustainable food.

TECHNOLOGY, SCIENCE, AND FUNDAMENTAL RESEARCH

While the global food system provides enough calories,[4] we fail to deliver an adequate and healthy food distribution for an ever-expanding global population. Malnutrition in all its forms persists and food insecurity is increasing. Deteriorating ecosystems and environmental challenges present various governance and stewardship issues, from who owns the land to who takes care of it, which contribute to uncertainties regarding future food supply. Although scientific advances have enhanced the productive potential of current farming systems, they have also revealed a range of stressors. These include declining soil health, increasing risks from both biological and non-biological factors, debates at local and global levels about the regulation and governance of innovative technologies, as well as questions of ownership and control. While embraced by many countries, specific technologies like genetic modification and gene editing have generated significant controversy and have yet to receive global acceptance. Agricultural sustainability, both economic and environmental, continues to drive research. However, policy, technology and behavioural change that enable adoption continue to lag behind research, limiting our ability to apply new knowledge to increasingly complex problems.

3 See, for example: Wittman, Hannah, Annette Aurélie Desmarais, and Nettie Wiebe, eds. Food sovereignty: Reconnecting food, nature & community. Halifax: Fernwood, 2010; Huambachano, Mariaelena. Recovering Our Ancestral Foodways: Indigenous Traditions as a Recipe for Living Well. Univ of California Press, 2024; Coté, Charlotte. A drum in one hand, a Sockeye in the other: Stories of indigenous food sovereignty from the northwest coast. University of Washington Press, 2022.

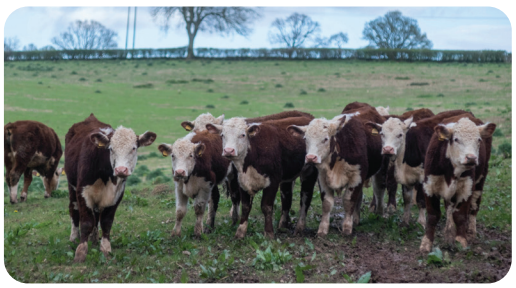
4 Berners-Lee, M., C. Kennelly, R. Watson, and C. N. Hewitt. "Current Global Food Production Is Sufficient to Meet Human Nutritional Needs in 2050 Provided There Is Radical Societal Adaptation." *Elementa: Science of the Anthropocene* 6 (2018): 52.

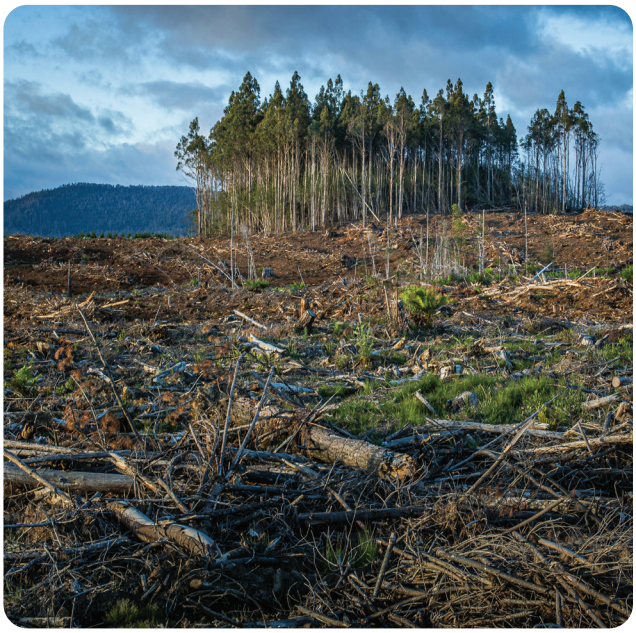
Digitization and artificial intelligence offer new ways of handling complex data and advancing understanding, but we face challenges in adopting and using these novel technologies. Questions about who owns data and how we steward its use to improve economic and social advancement remain open to debate. Some proponents want to directly invest in and exploit these opportunities while others assert that these technologies are simply codifying and stealing traditional knowledge that is vested in communities around the world. There is an active debate about whether food (and the soil it is grown on) — a basic necessity of biological life and life in society — should be treated as just another commercial good or whether it has unique public and social benefits that warrant different stewardship, governance and regulatory frameworks, such as the concept of a "Food Commons."[5] Current governance systems cannot comprehensively manage all of the emerging demands resulting from new technologies within, and applied to, the food system.

There is a recognition that, while critical to the future of food, technological advances alone are insufficient to ensure the success of the future food system. Instead, progress on key technologies will yield critical benefits and additional complexities that influence how and what we eat. The food system and the future of that system is complex and interconnected to such a degree that technological progress is only one part of that complexity and not a silver bullet. Below, we focus on significant themes of the food system that require additional focused fundamental research that could produce transformative change. The list is not exhaustive; this reflects the Panel's views that the integration of climate challenges, diverse knowledge, and the fundamentally social nature of food are central for a transformative agenda and would benefit from long-term, interdisciplinary, and global research efforts.

CLIMATE CHANGE & THE FOOD SYSTEM

The food system is both a driver of, and driven by, climate change. Food production, distribution, processing, and consumption are significant sources of greenhouse gas emissions. Methane from livestock, nitrous oxide from fertilizers, and carbon dioxide from deforestation and soil degradation are major contributors. Energy-intensive processes like food processing, refrigeration, and transportation further contribute to emissions, while the depletion of natural carbon sinks like forests and wetlands amplifies atmospheric carbon dioxide levels.





Photos (clockwise): Daniel Fikri, Matt Palmer, Veronica White

5 Jose Luis Vivero Pol. "Transition Towards a Food Commons Regime: Re-Commoning Food to Crowd-Feed the World." *SSRN*, January 13, 2015. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2548928.

Animal agriculture plays an outsized role in this dynamic, disproportionately affecting land use and climate change. Livestock production uses nearly 80% of global agricultural land while providing only 18% of global calories and 38% of the world's protein.[6] The extensive land required for grazing and growing feed crops like soy and maize drives deforestation, biodiversity loss, and ecosystem disruption, releasing large amounts of carbon stored in forests and soils. These land-use changes degrade soil health, reducing its capacity to sequester carbon, further exacerbating climate impacts.

Climate change is profoundly affecting the food system, with rising temperatures, raging fires, shifting rainfall patterns, and more frequent extreme weather events impacting crop yields, livestock health, and fisheries. These impacts are unevenly distributed, often hitting food-insecure regions hardest and creating feedback loops that threaten both food security and environmental resilience.

The impact of these issues in the coming decades will depend heavily on global efforts to transform the food system. Food system emissions will continue to rise without intervention, driven by population growth, dietary shifts, and agricultural expansion, exacerbating this negative feedback loop. Changes in policy, consumer behaviour, food system technologies and farming practices all hold the potential to transition the food system from being a primary driver of climate change to a key component of its mitigation, leveraging its potential to sequester carbon, restore ecosystems, and enhance resilience.

Addressing the intersection of climate change and the food system requires moving beyond isolated solutions toward systemic transformation. While targeted changes — such as reducing meat consumption, improving agricultural efficiency, or advancing carbon sequestration — may offer benefits, no single intervention can resolve the deeply interconnected challenges at play. The food system is shaped by economic structures, cultural traditions, technological capabilities, and ecological constraints, all interacting in complex and sometimes unpredictable ways. Meaningful progress demands a long-term, interdisciplinary, and globally informed fundamental understanding of the system. Scientific research, policy innovation, and shifts in consumer behavior must align with governance structures that recognize both local needs and planetary boundaries.

DIVERSE KNOWLEDGE SYSTEMS

Integrating diverse knowledge systems, including Indigenous perspectives and community-led initiatives, in developing governance models will create more resilient, equitable, and sustainable food systems. These models can serve as an opportunity to modernize food system governance in a manner that allows for increasing responsiveness by the food and agricultural sector to contemporary challenges, while additionally increasing public trust and relevancy through strengthening discovery and regulatory science that enable food system sustainability. The enabling of Indigenous leadership capacity and the emergence of knowledge weaving across global climate change and biodiversity initiatives have provided frameworks and case studies on the value of knowledge and governance model diversity.

Today, Indigenous people make up approximately 6% of the global population and are stewards of 20% of the earth's land mass.[7] Resilient, diverse, ecosystems and traditional knowledge have sustained humans since our earliest ancestors emerged. Historically, Indigenous agriculture has embraced sustainable practices, such as crop rotation and interplanting, as evidenced by the tradition of the Three Sisters, where three crops work together for success. While some traditional Indigenous seeds and crops may now be considered "forgotten foods," they also could be the answer to climate resilient crops and derisking food security for the future. Traditional food and knowledge systems play an important role in sustaining biodiversity around the globe: from the Arctic, to tropical rainforests, coastal regions and desert ecosystems and hold important clues to creating future sustainable food systems. Indigenous food systems celebrate biodiversity, resilience, and a spiritual relationship with nature, preserving both cultural heritage and ecological balance. Including Indigenous perspectives, agricultural practices, and diverse ways of knowing are key to the future of food systems.

6 Hannah Ritchie and Max Roser. "Half of the World's Habitable Land Is Used for Agriculture." *Our World in Data*, 2019. https://ourworldindata.org/global-land-for-agriculture.

7 Eugenia Recio and Dina Heastad. "Indigenous Peoples: Defending an Environment for All." *Policy Brief* 36, April 2022. https://www.iisd.org/articles/deep-dive/indigenous-peoples-defending-environment-all.

THE SOCIAL & CULTURAL VALUE OF FOOD

Food is more than just sustenance, much more than just calories and nutrients; it also carries significant social, economic, political and emotional value.[8] It can symbolize wealth, tradition, and identity. Food systems affect health, the environment, and social structures, prompting discussions about sustainability and ethical consumption. Understanding this value encourages critical thinking about what we eat and why. Food is a central element of cultural identity and expression. It reflects history, geography, and social norms. Traditional recipes and cooking methods are often passed down through generations, reinforcing community bonds. Festivals and rituals often center around food, showcasing its ability to bring people together and celebrate shared heritage.[9] Certain foods carry symbolic meanings. For example, rice is considered a staple and a symbol of fertility in many Asian cultures, while bread represents sustenance and hospitality in various traditions.

A greater understanding of the social and cultural value of food is essential for ensuring strong future food systems. Research and intervention will need to account for the deep-rooted connections between food, identity, and tradition. As globalization, climate change, and technological advancements reshape food systems, it is critical to ensure that cultural diversity, traditional knowledge, and social cohesion remain at the center of discussions. Food is not just a commodity — it is a fundamental part of the fabric that makes societies resilient and adaptive. A future-oriented approach to food system transformation must integrate these dimensions to ensure that they are not only scientifically and economically viable, but also socially and culturally meaningful.

8 Jean P. Enriquez and Juan C. Archila-Godinez, "Social and Cultural Influences on Food Choices: A Review," *Critical Reviews in Food Science and Nutrition* 62, no. 13 (2021): 3698–3704, https://doi.org/10.1080/10408398.2020.1870434.

9 Dallen J. Timothy and Miguel Pena, "Food Festivals and Heritage Awareness," in *Heritage Cuisines*, 1st ed. (New York: Routledge, 2015), 18.

ECOLOGY AND BIODIVERSITY

Ecology and biodiversity are the foundation of resilient and productive food systems, supporting everything from soil health and pollination to pest control and climate adaptation. The loss of biodiversity threatens food security by reducing the genetic diversity needed to withstand environmental stresses, making it essential to integrate ecological principles into the food system. Further, stewardship of natural resources is a collective responsibility. How can we safeguard land and water biodiversity? How do we adapt crops and animal agriculture and production systems to the new climate norms? These challenges require research on a broad range of issues related to the production of the animals and plants used in global agriculture, from basic sciences and breeding to soil science, management systems, processing and distribution.

THE ROLE OF SOIL

Soil health is foundational to all healthy terrestrial ecosystems. Healthy soil is defined as having "the ability to sustain the productivity, diversity, and environmental services of terrestrial ecosystems."[10] Soil health and human health are inextricably linked. For example, degraded soils often result in lower yields and degraded food quality, perpetuating poverty and increasing the risk of malnutrition, micronutrient deficiencies, and other related health issues.[11] Soil health is critical to addressing some of the most pressing challenges facing humanity today, including climate change, mass loss of biodiversity and rising levels of food insecurity.

There is a critical need to embrace past knowledge, technology and innovation to better understand the interconnectedness between soil health, plant health, human health and planetary health, and to identify key land management pathways that can ensure soil health. Over one-third of the earth's surface is currently considered degraded,[12] with soil erosion as the most prevalent form of land and soil degradation.[13] A recent review highlights the current state of knowledge of the impact of climate change on the soil microbiome and the potential for microbial activities to mitigate these effects.[14] Soil biodiversity contributes to multiple ecosystem services and functions, many of which we are just discovering and mapping.[15] As soil is a significant sink for carbon, understanding how land management practices impact the soil carbon cycle as well as the soil microbiome is critical.[16]

10 Intergovernmental Technical Panel on Soils, Food and Agriculture Organization of the United Nations. *Towards a Definition of Soil Health. Soil Letters #1*, September 2020. https://openknowledge.fao.org/_server/api/core/bitstreams/ffb5feaf-8388-4e2f-b319-2260a9a6f5a2/content.

11 Lal, R. "Challenges and Opportunities in Soil Organic Matter Research." *European Journal of Soil Science*, March 13, 2009. https://doi.org/10.1111/j.1365-2389.2008.01114.x.

12 IPBES. *The IPBES Assessment Report on Land Degradation and Restoration*. Edited by L. Montanarella, R. Scholes, and A. Brainich. Bonn, Germany: Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2018. https://doi.org/10.5281/zenodo.3237392.

13 Vagen, Tor-Gunnar, and Leigh Ann Winowiecki. "Predicting the Spatial Distribution and Severity of Soil Erosion in the Global Tropics Using Satellite Remote Sensing." *Remote Sensing* 11, no. 15 (2019): 1800. https://doi.org/10.3390/rs11151800.

14 Jansson, Janet K., and Kirsten S. Hofmockel. "Soil Microbiomes and Climate Change." *Nature Reviews Microbiology* 18 (2020): 35–46. https://doi.org/10.1038/s41579-019-0265-7.

15 Delgado-Baquerizo, M., P. Reich, C. Trivedi, D. Eldridge, S. Abades, F. Alfaro, et al. "Multiple Elements of Soil Biodiversity Drive Ecosystem Functions Across Biomes." *Nature Ecology & Evolution* 4, no. 2 (2020): 210–220. http://dx.doi.org/10.1038/s41559-019-1084-y.

16 In East Africa for example, research has found that eroded soils have up to 50% less carbon than non-eroded soils.

THE ROLE OF TREES

We cannot have a conversation about transforming food production systems to reduce negative environmental impacts without talking about trees.

One of our greatest solutions to issues of soil degradation is agroforestry — leveraging the power of trees on farms, as windbreaks, or riparian buffers, or incorporating them directly into crop or animal production practices. When implemented at scale, agroforestry could increase food security for 1.3 billion people, it can reduce soil erosion by 50%, and it can increase soil organic carbon by 21%. It can also contribute to significant emission reductions and healthy, biodiverse ecosystems. About 85 percent of Nationally Determined Contributions now mention agroforestry as a strategy for achieving targets without external financial support.[17]

Integrating agroecological, sustainable, and regenerative agricultural practices and agroforestry, based on science and robust data offer the possibility of feeding the world and protecting forests. This requires working with farmers to build incentives for new practices, to enhance productivity on their farms, and to engage with evidence.[18] The 2024 Living Planet report highlights the fact that three-quarters of agrifood emissions come from low to middle income countries. Unfortunately, not enough money is invested in holistic strategies that cut agrifood emissions. As a sector, agroforestry lags behind others in financing for climate action, even when we have investable solutions that can catalyze green growth.[19] For example, in Kenya, we see new tree-based economies that can generate 10x more revenue than tourism brings in. Too often, these solutions are left out of the conversation. Projects like Regreening Africa, recognized as a World Restoration Flagship at UNEA in February 2024, demonstrate the power of farmer-led ecosystem regeneration.

Photos (left to right): Michael Muli, Collin Wulr

17 Zhu, X., W. Liu, J. Chen, et al. "Reductions in Water, Soil and Nutrient Losses and Pesticide Pollution in Agroforestry Practices: A Review of Evidence and Processes." *Plant and Soil* 453 (2020): 45–86. https://doi.org/10.1007/s11104-019-04377-3.

18 Putting participatory research for development to action — on the ground with communities. Even when governments and companies embrace change, they require help to work across sectors, disciplines, and data to address complexity. CIFOR-ICRAF brings cutting-edge research insights into development actions to guide stakeholders across the value chain and across sectors. For more details, visit https://www.cifor-icraf.org.

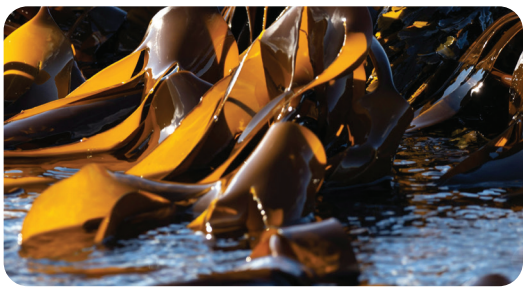
19 Green growth in the context of agroforestry and the food system refers to an economic approach that enhances food production while maintaining ecological integrity, reducing emissions, and promoting biodiversity. It emphasizes sustainable land-use practices that support both economic development and long-term environmental resilience. https://www.unescap.org/our-work/environment-development/sustainability-transitions/green-growth.

By restoring degraded lands, they become more productive and pressures to cut down standing forests for agriculture are reduced. High organic matter in soil, the foundation for functioning ecosystems, including sustainable agricultural systems, is critical in this. If we are to transform our food systems to be climate-resilient and sustainable, the change begins both on the ground in grassroots initiatives — through national policies and frameworks, and through global initiatives. How can we move from resource intensive agriculture to knowledge intensive agriculture, the basis for regenerative food systems? Every corner of our globe should have equal access to scientific advancements that promote nature positive net zero food systems to improve lives and safeguard our planet through agroecology and agroforestry.

Agroforestry is more than a tool for agricultural and economic diversification; it is a deep-rooted foundation of ecological intensification and landscapes improvement, driving resource efficiency, enhancing resilience, and serving as a vital lever in the agroecological transformation of global food systems and local landscapes.

THE ROLE OF AQUATIC FOODS

The demand for fish has roughly doubled since the turn of the century and will likely double again by 2050, however, this demand will vary around the world.[20] While there are indications that some major fish stocks are not yet fully exploited, catches from wild capture fisheries are unlikely to further expand. Aquaculture's contribution to global fish consumption by weight has reached parity with capture fisheries and has room to grow. Some aquaculture has been associated with negative environmental effects related to feed and habitat degradation.[21] While these impacts are seen in some systems, such as shrimp and salmon production, there are a range of lower trophic species that can even have a net positive environmental impact by extracting ambient nutrients. Species which include mollusks (e.g., oysters, mussels, clams, and scallops), seaweed and macroalgae (e.g., kelp, nori, wakame), herbivorous and detritivorous fish (e.g., tilapia, silver carp, and milkfish), echinoderms (e.g., sea cucumbers), all have greater potential use in this context.



Photos (clockwise): Janet Serhan, Ben Wicks, Anthony Camp

20 Naylor, R. L., A. Kishore, U. R. Sumaila, et al. "Blue Food Demand Across Geographic and Temporal Scales." *Nature Communications* 12 (2021): 5413. https://doi.org/10.1038/s41467-021-25516-4.

21 Gephart, J. A., P. J. G. Henriksson, R. W. R. Parker, et al. "Environmental Performance of Blue Foods." *Nature* 597 (2021): 360–365. https://doi.org/10.1038/s41586-021-03889-2.

Three quarters of aquaculture production today is in freshwater systems, growing a range of omnivorous or herbivorous species, mainly across Asia. There is increasing attention to the expansion of these freshwater systems in Africa to support improved nutrition security. At the same time, there remains considerable potential for expanding unfed lower trophic marine aquaculture systems, such as bivalves and seaweeds.

In many parts of the world commercial large-scale aquaculture is very much in its early stages. The scale of the world's oceans and fresh water systems suggests that this may be the next frontier for the future of high-quality animal protein production to meet the ever-increasing demands of an expanding population.

To date, aquaculture research has focused mainly on the globally traded species that make up 10 to 20% of global production — namely, species such as salmon, shrimp and tilapia. Far more attention is needed on the other 600 plus species that are currently grown around the world — in both freshwater and marine systems.[22] Questions on improved feeds, lower carrying and accessible production technologies and managing environmental impacts need to be answered, especially in regions such as Africa. Research is also needed to contribute new approaches for governing the sustainability of aquaculture from a food systems perspective — taking into consideration not only production, but also the ways in which farmed organisms are made available through trade and integrated into consumption practices.

22 Golden, C. D., J. Z. Koehn, A. Shepon, et al. "Aquatic Foods to Nourish Nations." *Nature* 598 (2021): 315–320. https://doi.org/10.1038/s41586-021-03917-1.

CULTURE, CHOICE, AND BEHAVIOUR

Food both shapes and is shaped by culture. What people eat can be a political statement, a declaration of identity, or a way for migrants and diaspora communities to stay connected to home. Shifting consumer choices toward healthier and more sustainable diets is a powerful lever for food system transformation, but achieving this change is challenging. Unhealthy food environments, limited education on nutrition, and the influence of large food companies — through marketing, large-scale advertising, and social media outreach — make it difficult to shift perceptions and behaviors, particularly regarding ultra-processed foods like sugar-sweetened beverages. However, consumer choice alone cannot drive systemic change, as individual food decisions are shaped by broader structural factors such as economic inequality, corporate influence, and policy frameworks. Research on how education, social networks, and key influencers — including women, who often play a central role in food systems as producers, caregivers, and decision-makers — can shift structural conditions is crucial. Rather than placing the burden on individuals, efforts to transform food environments must address the policies, power structures, and cultural forces that shape what is available, affordable, and desirable to eat.

EDUCATION

Formal and informal education can and should play a major role in shaping consumption patterns and encouraging healthier diets and lifestyles, yet it is often undervalued and often not explicitly incorporated into food policies.

Innovative education efforts on healthy and sustainable food choices at schools, community spaces, and workplaces can have meaningful impact. Formal education may include programs at schools and universities; training through community gardens, urban farms, and cooperative extension; and certificate programs aimed at holistic understandings of nutrition. Formal education establishments can also facilitate healthy food environments by ensuring healthy foods are easily accessible at schools (and unhealthy foods are restricted). Informal education extends even more broadly, to include spaces of influence like social media environments (working with chefs, nutritionists, and others with large social media followings), religious community centers, public libraries and other gathering places, public festivals, and various service organizations. Identifying how to bring positive food messaging into these informal educational spaces and encouraging healthy diet choices will be key in the future of the food system.

Overall, identifying effective education programs or interventions that promote healthy choices and transformation of diets as well as greater involvement and agency in food systems is critical. One notable model that implements this approach is the edible schoolyard initiative, which uses a food system lens to teach students academic subjects as well as food, nutrition, stewardship, and community in kitchens, school gardens, and cafeterias. Another important path of research is around behavioral economics through nudging and adjusting the architecture of choice. There is enough encouragement and early evidence to expand education efforts in this realm.

Education should be a key tool to lay the foundations for leadership that will advocate and enhance sustainable food systems across industry, NGOs, and public arenas and be appropriately tailored to all different facets of society (e.g., minorities, gender, age, religion).

INFLUENCE(RS)

Social media has been a two edged sword. On the one hand, influencers and profit-maximizing algorithms have spread false or evidence-lacking claims and often driven consumers to unhealthy food choices with a large environmental footprint that lead to health, environmental or social harms. On the other hand, social media has radically transformed how cultural influences are transmitted. This effect has been central to dietary change, especially among young people. Building on the earlier popularity of food blogging, social media platforms that rely on visual content (like Facebook, Instagram, YouTube and Tiktok among others) have been especially important in the food realm, given the visual appeal of food preparation and presentation. Restaurants have rebranded and redecorated to create menus, interior design, and lighting that are photogenic, or "Instagrammable." Chefs, home cooks, and industry professionals present their recipes and cooking techniques through eye-catching video content. Beautiful, sensual photographs of food, styled and lit with a professional flair, have created a genre of "food porn" that draws viewers. All of these have concrete, yet largely unconscious, effects on the foods that viewers and consumers choose to purchase, eat, and thus promote the production of. As food and media studies scholars Emily J. H. Contois and Zenia Kish write, "Instagram [and other social media] . . . helps to *produce* food systems through its visual economy, linking farms to food bloggers to restaurants to eaters in novel and potentially profitable ways."[23] Social media will likely continue to increase in influence, reshaping human diets and food systems in tangible ways. More attention to the role of this revolutionary part of our food economy, and ways to harness it to promote sustainable food systems, is necessary.

When considering the tremendous influence of the processed food, meat, and dairy industries, promoting consumption of their products, it is important to understand the role of trade organizations and other federations that bring different companies together to assume even larger scales of power. One example is the Protein Pact, which brings together meat and dairy industry players in the USA to market meat and dairy protein as central for "the people, animals and climate of tomorrow."[24] This umbrella organization has been working to pay social media influencers and dietitians to promote protein, while downplaying its role in climate change.[25] This is the kind of food industry positioning that currently shapes consumer education around food and nutrition; any move in the direction of sustainable food futures must take into account these kinds of vested interests, industry-sponsored lobbying and counterpressure, and perhaps co-opt some of its practices in the opposite direction.

THE ROLE OF WOMEN

There has been a traditional association of women and motherhood with food, and women's role in feeding the family and community. The relationship between food and gender highlights how societal norms shape food-related roles. Historically, women have often been associated with cooking and caregiving, while men are frequently linked to hunting, meat consumption and culinary authority. This dynamic can influence food choices, health outcomes, and economic roles in both domestic and professional settings.

In many Indigenous communities, women are recognized as key knowledge holders, especially regarding food systems, biodiversity, and ecological stewardship. Their roles go beyond cultivation to include seed saving, land management, and the transmission of knowledge across generations. Today, Indigenous women are increasingly taking the lead in agroecological practices, blending traditional ecological knowledge with modern farming innovations to improve sustainability and resilience. By viewing farming as a holistic practice deeply rooted in culture, health, and community well-being, they challenge industrial agricultural models and advocate for food sovereignty, regenerative practices, and localized food economies.[26]

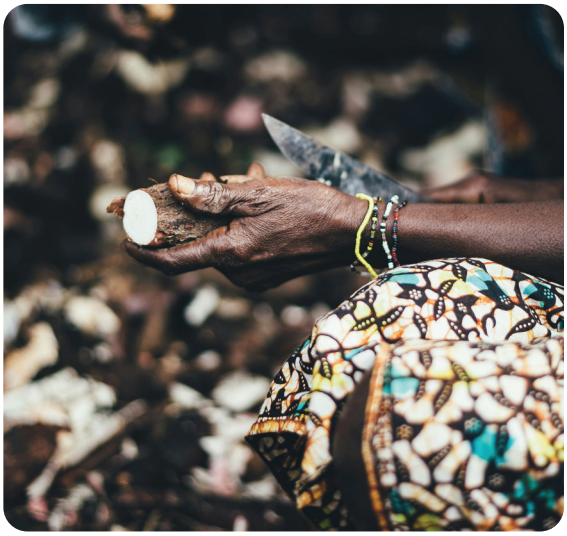
23 Contois, Emily J. H., and Zenia Kish, eds. *Food Instagram: Identity, Influence, & Negotiation.* Urbana: University of Illinois Press, 2022.

24 The Protein Pact. https://theproteinpact.org.

25 Jenny Splitter. "What You Need to Know About the Meat Industry-Funded 'Protein Pact'." *Sentient Media.* https://sentientmedia.org/meat-industry-funded-protein-pact.

26 Mariaelena Huambachano. "Seeding a Movement: Indigenous Food Sovereignty." *University of Miami Law Review* 78 (2023): 390. https://globalaffairs.org/commentary-and-analysis/blogs/flavors-and-culture-food-systems-through-indigenous-womens-eyes. "Rural Women in Agroecology at Panela Cheia Farm and Cooplantas." *SIANI.* https://www.siani.se/news-story/rural-women-in-agroecology-at-panela-cheia-farm-and-cooplantas.

Rural women make up nearly 45 percent of the global agricultural workforce, and in developing countries, they are "responsible for producing between 60 and 80 percent of all food."[27] However, there are large gaps in terms of access to land and services, decision power, and significant income disparities. As noted by the Africa Food Systems Forum, "rural women are the guardians of our food traditions, the keepers of our biodiversity and the pillars of our food systems."[28] One example, combining the role of women in food production and novel technologies to reduce drudgery, is cassava. Cassava is a major staple starch throughout the world and particularly in Africa, and it is primarily produced and processed by women. In West Africa, women can spend up to 800 hours processing up to 15 tonnes of fresh cassava roots to prepare one tonne of the traditional fermented food *garri*. Using cassava varieties developed through modern breeding, the amount of cassava roots required can be reduced to less than 5 tons and the amount of women's labour required to less than 500 hundred hours, thus dramatically reducing the time required to prepare it.[29] There is also a notion of "women's crops," that traditionally are nutritious and climate resilient, but have less value on the market. Analyzing food through a gender lens reveals deeper insights into power dynamics, expectations, and the construction of identities.[30]



Photos (left to right): David Monniaux, Annie Spratt

27 UNDP. "Celebrating Rural Women's Roles in Transforming Food Systems." *United Nations Development Programme*, October 12, 2023. https://www.undp.org/blog/celebrating-rural-womens-roles-transforming-food-systems.

28 Amath Pathé Sene. "Rural Women Play a Transformative Role in Food Systems." *Farming First*, December 8, 2023. https://farmingfirst.org/2023/12/rural-women-play-a-transformative-role-in-food-systems.

29 Bouniol, A., H. Ceballos, B. Abolore, et al. "Varietal Impact on Women's Labour, Workload and Related Drudgery in Processing Root, Tuber, and Banana Crops. Focus on Cassava in Sub-Saharan Africa." *Journal of the Science of Food and Agriculture*, 2023. https://doi.org/10.1002/jsfa.12936.

30 Corinna Hawkes, C. Gallagher-Squires, M. Spires, et al., "The Full Picture of People's Realities Must Be Considered to Deliver Better Diets for All," *Nature Food* 5 (2024): 894–900, https://doi.org/10.1038/s43016-024-01064-0.

CONCLUSION, KEY RESEARCH QUESTIONS & THE WAY FORWARD

The global food system is extraordinarily complex and diverse, encompassing food production, transportation, international trade and processing industries, consumption and disposal and the various levels of policy and regulation overlaying each of these sectors that get food from around the world to our plates every day. The overall recent history of the world's food system includes many kinds of successes: the twentieth-century Green Revolution increased agricultural productivity, reduced malnutrition, and globalization of the food industry increased availability, diversity, and security of supply.

However, these successes brought with them many failures. At every level of the food system challenges exist: immediate issues of adaptation to climate change, environmental degradation, the scarcity of water resources and the urgent need to reduce the carbon footprint of the food chain, to labor inequities, animal welfare, impacts of transportation and processing, increasing concerns regarding food insecurity, poor nutrition, and rising levels of diet-related disease. There is a need for greater understanding of the dynamics of these complex and diverse aspects of the global food system, in order to build a more sustainable and just future food system.

Addressing these challenges requires moving beyond reactive solutions to a deeper, more systemic understanding of the forces shaping our food systems. We can identify the most critical leverage points for long-term transformation by integrating insights from across disciplines. The following research questions emerge from this integrated perspective, highlighting key areas where fundamental inquiry can drive meaningful change in food production, consumption, and governance.

1. HOW CAN WE REIMAGINE FOOD PRODUCTION, BLENDING THE NEEDS OF THE FOOD SYSTEM, PEOPLE AND THE EARTH?

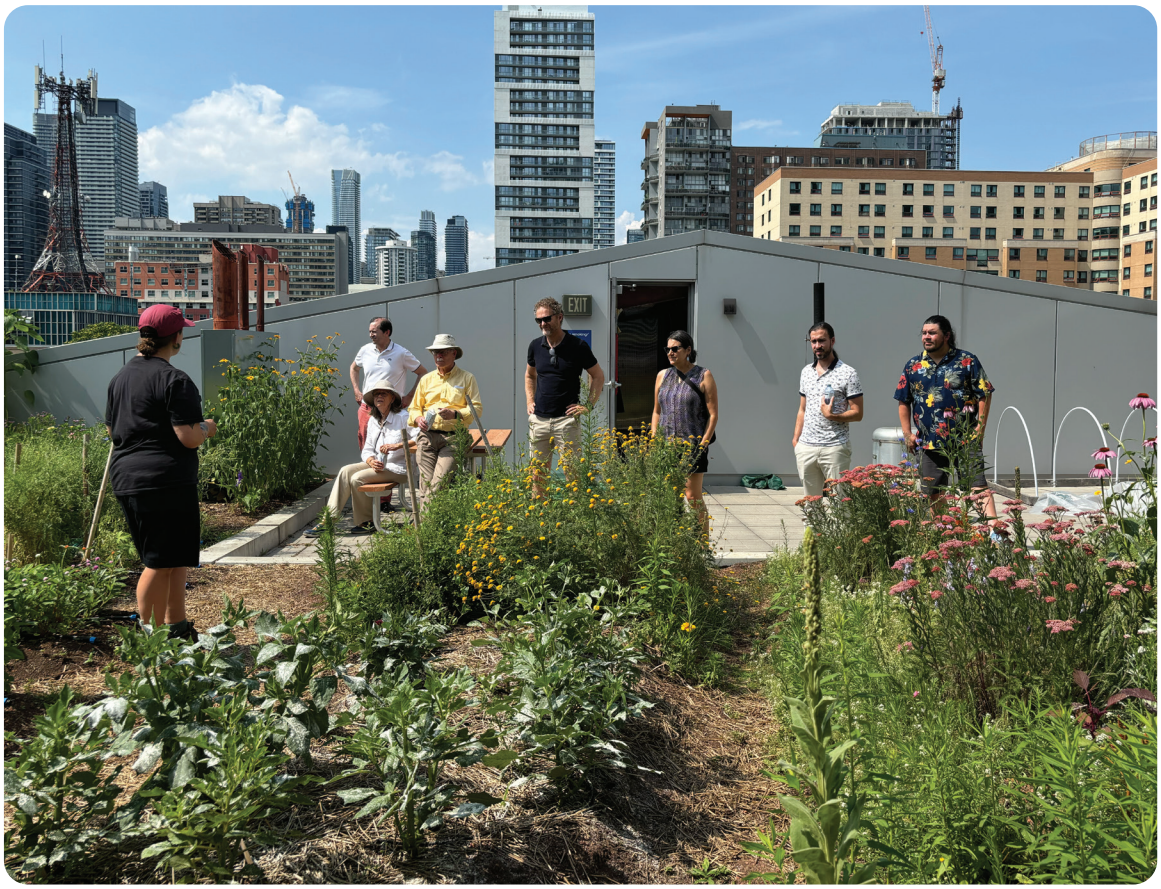
Reimagining food production requires a systems-level approach that aligns agricultural practices with planetary boundaries, while addressing a growing global population's nutritional and economic needs. This involves blending food and Earth systems to balance productivity with ecological sustainability. Key focus areas include mitigating the impacts of primary food production on soil health, biodiversity, and using natural resources like water and land. Soil health, in particular, is foundational, linking ecosystem resilience to human health. Addressing the dual role of food production as both a driver and mitigator of climate change is crucial, with efforts to decarbonize food production practices, improve land and water management practices, and adapt to changing climate conditions.

Innovation is essential, particularly in diversifying food production systems. Advances in genomics and the development of novel crops and crop systems, the expansion of aquatic food systems and the introduction of new climate-resilient crops, hold significant potential. Incorporating indigenous knowledge of traditional practices and management of land and water resources is also key. Integrating fundamental research across these key areas can address critical issues, such as food security, emissions reduction, ecosystem restoration and overall food system resilience. An integrated approach will be necessary for transforming food systems into engines of planetary and human health.

2. HOW CAN WE UNDERSTAND AND SHAPE THE INTERDEPENDENCIES BETWEEN INDIVIDUAL CHOICES, NUTRITION, AND HUMAN HEALTH?

Individual food choices are shaped not only by personal preference, but by a complex web of constraints, including socioeconomic status, regional disparities in food production and distribution, and cultural influences. Unequal access to healthy, sustainable food options raises essential questions about who truly can choose what they eat and how these choices impact health outcomes. Addressing these disparities requires a deeper understanding of not just consumer behavior, advertising, education, and industry lobbying, but also the daily food practices that shape and reinforce dietary habits over time. Structural barriers — such as food affordability, accessibility, and time constraints — often override intentions, making it crucial to move beyond a focus on individual responsibility and instead reshape the environments and systems that define what is possible, practical, and desirable to eat.

The psychology and practice of food choice are deeply tied to public health outcomes, yet behavior change is not simply a matter of education or awareness. The attitude-behavior gap — where people may express a desire to eat healthily but struggle to act on those intentions — illustrates the power of habitual and socially embedded food practices. Industries promoting ultra-processed foods leverage advertising and lobbying to reinforce these consumption patterns, making unhealthy options the norm rather than the exception. Understanding how food choices emerge within the context of daily life — not just as isolated decisions, but as routines shaped by broader economic, social, and environmental conditions — will be critical to creating a food system that supports nutrition, sustainability, and resilience at a structural level.



The Discovery Panel visits the urban rooftop farm at Toronto Metropolitan University.

Photo: Lauren Goldstein

3. HOW DO FOOD PRACTICES AT INDIVIDUAL, CULTURAL, AND COMMUNITY LEVELS SCALE UP TO INFLUENCE GLOBAL SYSTEMS, AND HOW CAN GLOBAL DECISION-MAKING IMPACT LOCAL FOOD PRACTICES?

Food practices are deeply rooted in cultural, community, and individual contexts, yet they have cascading effects that influence global systems. Local governance frameworks, cultural traditions, and community practices shape food production and consumption, but these are increasingly interconnected with global decision-making. Governance across scales — from local communities to international frameworks — must address issues such as human and women's rights, cultural perspectives, and the economic drivers of food systems. Collaborative approaches to governance that integrate local knowledge with global priorities as well as diverse stakeholders (and viewpoints) are essential for creating equitable and resilient food systems.

As new production paradigms, technologies, and data systems emerge, their governance becomes a critical issue. The introduction of novel technologies and production practices must consider their impacts across scales, from local ecosystems to global markets. Cultural perspectives on food, agriculture, and consumption play a vital role in shaping these practices and ensuring their sustainability. Furthermore, the economics of food systems — encompassing production, processing, and distribution — need to be analyzed not only for efficiency, but also for equity and sustainability. By understanding how food practices at the individual and community level scale up to influence global decisions — and vice versa — we can design governance systems that foster inclusive, sustainable, and adaptive food systems for the future.

IN SUMMARY

Transforming the global food system requires more than incremental improvements — it demands a fundamental rethinking of how food is produced, distributed, consumed, and governed. The complexity of the challenges ahead — from environmental degradation to shifting dietary patterns — means that no single discipline, policy, or innovation will suffice. A deeper, more integrated understanding of food system dynamics is essential, one that brings together diverse perspectives from across the natural and social sciences, Indigenous knowledge systems, and global policy frameworks. Long-term, interdisciplinary research will be crucial for uncovering the underlying mechanisms that shape food system resilience, equity, and sustainability. By approaching food not just as a commodity but as a critical interface between human and planetary health, we can generate the knowledge needed to drive meaningful, systemic change. A global perspective is equally vital, recognizing that local food practices both influence and are shaped by international governance, economic forces, and environmental shifts. The next decades present an opportunity to reshape the food system in ways that align with both ecological limits and human well-being — an opportunity that will only be realized through sustained, collaborative, and forward-thinking research efforts.

APPENDIX I
DISCOVERY PANEL MEMBERS

DISCOVERY PANEL MEMBERS

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