Climate change and food systems interactions:

Ensuring resilient and healthy diets

Jessica Fanzo, Professor of Climate and Director of the Food for Humanity Initiative, Columbia Climate School
Alison Rose, Senior Program Manager, Food for Humanity Initiative, Columbia Climate School

Jessica Fanzo is a Professor of Climate and Director of the Food for Humanity Initiative at the Columbia Climate School. She specializes in global food policy, nutrition, and sustainability, with extensive experience in international development and humanitarian work. She has served as an advisor to various organizations, including the United Nations and the World Health Organization, advocating for resilient and equitable food systems. Her work aims to integrate science and policy to improve nutrition and health outcomes globally.

Food and the systems in which food is produced, processed, packaged, transported, sold, and consumed are becoming increasingly fragile with the changing climate. At the same time, how we grow food, what food we grow, and the trading and selling of these foods have profound consequences on the climate and environment. The world has benefited from technological advances in food systems, but we now stand at our breaking point. Malnutrition is worsening – both hunger and obesity are rising. Much of that malnutrition has to do with the types of diets we consume, which have contributed to adverse health outcomes. We must change the way we govern, manage, and engage with food systems if we want them to produce healthy diets that benefit everyone's health and nutrition. We need various solutions to do this, and food and climate communities must come together around common goals and actions.

INTRODUCTION

Over the last century, human consumption of energy, food, transport, and infrastructure, land use change, and changing lifestyle patterns have been the primary sources of increased greenhouse gas emissions worldwide. These emissions have increased global surface temperatures and led to massive and expedited changes in earth systems, including ocean and biosphere alterations. Due to these planetary boundary shifts, human-induced climate change alters weather and climate extremes, causing widespread adverse impacts, losses, and damages to both human society and nature.[1]

Food systems comprise all the activities, actors, and policies related to food production, storage, processing, packaging, transportation, and sale in the global economy. The attributes of food systems can be wide-ranging, from global to hyperlocal. Food systems and climate change are in an intimate dance – one that could be beneficial or detrimental for life on this planet, depending on how we act. These systems are fragile and vulnerable to climate change and are not managed sustainably, resulting in devastating impacts on human health. However, there are solutions. It is up to the collective global citizenry to spur transformation and ensure that food systems are resilient and contribute positively to the planet.[2]

1 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, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001.

2 Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., ... & Murray, C. J. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet, 393(10170), 447-492.

FOOD SYSTEMS ARE VICTIMS

The impacts of near- and long-term climate variability and change will have widespread implications for food systems, including agriculture productivity and supply chains. Global warming is projected to alter what type and where crops are grown and their ability to generate enough yields to feed a population of 10 billion by 2050. Climate projection models have shown that more atmospheric carbon dioxide concentrations could challenge some crops, particularly maize grown in the tropics, to maintain current-day yields.[3] Various modeling studies also suggest that with elevated atmospheric carbon dioxide concentrations, crops such as wheat, rice, potatoes, and barley could lose their nutritional quality – with declines in the protein and micronutrient content – of highly consumed plant-based foods. These nutritional declines could exacerbate what is already an alarming global health crisis – over half of children under five years old are micronutrient deficient in either iron, zinc, or vitamin A, and two-thirds of women of reproductive age are micronutrient deficient in either or at least iron, zinc, and folate.

Other harmful effects of climate change are mediated through sea-level rise. Small Island Developing States and coastal areas of South Asia, Southeast Asia, and West Africa – where rice – and aquaculture-based production systems dominate – are at increasing risk from both encroachment by coastal waters as sea level rises and increased groundwater salinity. Salinization of soil and groundwater further limits the physical extent of land suitable for agricultural production, potentially exacerbating food insecurity and poor nutrition outcomes such as undernutrition and micronutrient deficiencies.

"Global warming is projected to alter what type and where crops are grown, as well as our ability to generate enough yields to feed a population projected to reach 10 billion by 2050."

While longer-term climate change projections paint a grim future, climate variability and extreme weather events, such as droughts, heat, and heavy precipitation, require more immediate attention because they impact food availability and access, diets, and nutrition outcomes.

The damage of extreme events such as droughts, heat waves, or floods on productive assets, infrastructure, and essential services can persist long after the shock has passed. Extreme events can decimate local and regional food systems by impacting production, transportation, storage, market and food environment access, and by causing the loss and waste of food. Until fairly recently, East Africa was experiencing an unprecedented drought, with multiple failed rainy seasons. The region has a history of droughts, so the compounding effects of repeated years exacerbated vulnerabilities. In Ethiopia, for example, this led to millions of people experiencing food insecurity over the years due to impacts on vegetation and livestock as well as rangeland degradation and water shortages.[4] Extreme weather events can also impact urban settings. In 2006, after Hurricane Katrina struck New Orleans, access to food was impacted through the closure of a significant proportion of supermarkets in the city. Two years later, the number of supermarkets still had not returned to pre-storm levels.[5] Extreme events hamper food supply chains and disrupt global food trade and distribution channels, making it harder for foods to be available in markets. Less predictable supplies create market speculation, significantly affecting physical and economic access to healthy diets.

These events also put people at significant risk for severe food insecurity and undernutrition, and failing food systems can impact the availability and physical and economic access to safe, diverse, and healthy diets. For example, across 19 studied countries, higher long-term temperatures were associated with lower dietary diversity.[6] Another related study found that periods of minor to severe drought and severe wetness were correlated with more stunting (a measure of chronic undernutrition) among children across 53 low – and middle-income countries.[7] Lastly, a study in 5 countries in West Africa found that lifetime exposure to temperatures above 35°C increases the prevalence in young children of stunting by 18% and wasting (defined as low weight-for-height) by 16%. A permanent 2.0°C rise in average global temperatures above preindustrial levels is estimated to increase stunting by 7%.[8]

Climate change affects diets and nutrition outcomes through various food and health pathways, as shown in **Figure 1.** Direct climate effects will impact not only food quantity and quality but also water quality. This, in turn, will affect food and water security and the ability to access quality, diverse diets. Climate change and extreme weather events impact the quantity and quality of food available, exacerbate food inflation and prices, and reduce the affordability of a healthy diet, particularly for low-income and vulnerable populations. This reduction in food affordability is compounded by increased economic losses (for example, lost livelihoods).

3 Jägermeyr, J., Müller, C., Ruane, A. C., Elliott, J., Balkovic, J., Castillo, O., ... & Rosenzweig, C. (2021). Climate impacts on global agriculture emerge earlier in new generation of climate and crop models. Nature Food, 2(11), 873-885.

4 World Health Organization. (2024, May 7). Snapshot: Greater Horn of Africa food insecurity and health - grade 3 emergency: 31 March 2024. World Health Organization. https://www.who.int/emergencies/greater-horn-of-africa-food-insecurity-health-snapshot.

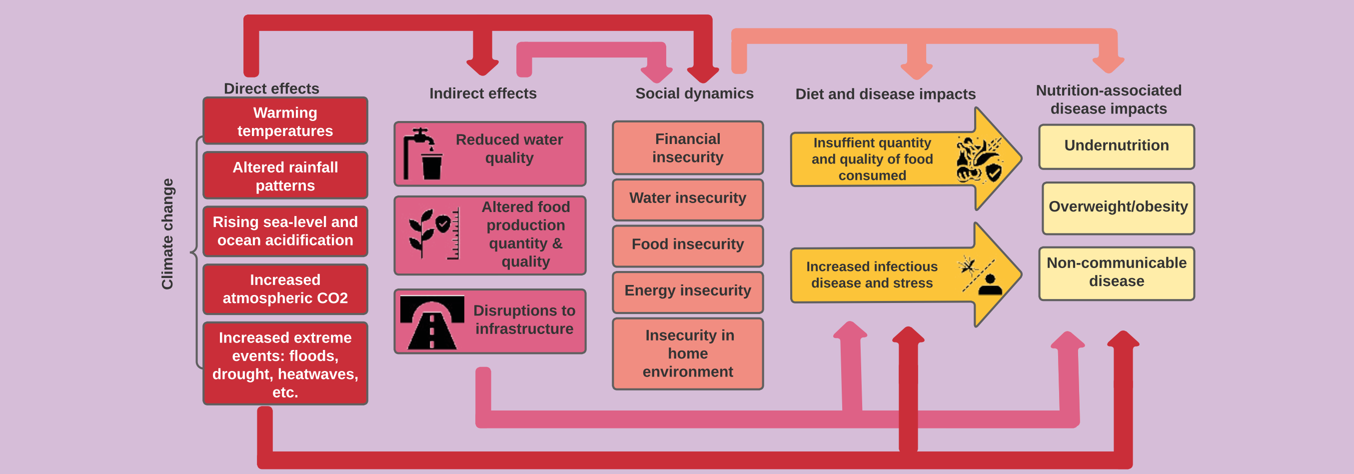
5 Foster, A. M. (2024, July 24). Food Access five years after the storm. Center for American Progress. https://www.americanprogress.org/article/food-access-five-years-after-the-storm/.

6 Brown, M. E., Grace, K., Shively, G., Johnson, K. B., & Carroll, M. (2014). Using satellite remote sensing and household survey data to assess human health and nutrition response to environmental change. Population and environment, 36(1), 48-72.

7 Brown, M. E., Backer, D., Billing, T., White, P., Grace, K., Doocy, S., & Huth, P. (2020). Empirical studies of factors associated with child malnutrition: highlighting the evidence about climate and conflict shocks. Food Security, 12, 1241-1252.

8 Blom, S., Ortiz-Bobea, A., & Hoddinott, J. (2022). Heat exposure and child nutrition: Evidence from West Africa. Journal of Environmental Economics and Management, 115, 102698.

Figure 1: Climate change has impacts on diets and nutrition-associated diseases



Source: Fanzo, J.C. and Downs, S.M., 2021. Climate change and nutrition-associated diseases. *Nature Reviews Disease Primers, 7*(1), p.90.

Already, 3 billion people cannot afford what is considered a healthy diet – one that meets nutrient needs and is health protective – and diets are now a top risk factor of disease and death globally. Even in high-income countries, modeling shows that climate change-associated reduction in fruit and vegetable consumption is the leading risk factor for diet-related non-communicable diseases (such as cardiovascular disease, diabetes, and some cancers).

To paint a stark picture, the quality of the world's diets and nutrition are declining. Diets are now one of the top risk factors for disease and death in the world. Hunger has been rising over the last five years, primarily due to climate change, conflict, and the economic downturn of the COVID-19 pandemic. Stunting has been declining, but still, over 20% of the world's children under the age of five suffer from it. Overweight and obesity, significant risk factors for non-communicable diseases, are rising everywhere. The global prevalence of obesity more than doubled between 1990 and 2022.[9] In North America, for example, 34% of the adult population is overweight and another 32% is obese. Not one country has been able to halt the upward trends of obesity across all ages.

> *"To paint a stark picture, the quality of the world's diets and nutrition are declining. Diets are now one of the top risk factors for disease and death in the world."*

FOOD SYSTEMS ARE INSTIGATORS

While food systems are vulnerable to climate change, they also contribute to climate change and environmental degradation. Food systems are estimated to generate approximately 30% of the total greenhouse gas emissions globally, contributing to all three major gases – carbon dioxide, methane, and nitrous oxide. Most carbon dioxide emissions come from land use change, largely deforestation due to livestock and oil seed crops (such as soy and palm) and on-farm agriculture production.

Livestock (mainly cattle for beef, dairy, and sheep) and rice paddy production are major methane emitters, and food systems generate the most methane, a toxic, short-lived greenhouse gas. Nitrous oxide mainly comes from fertilizer use on crops.

Food systems are also significant contributors to environmental and natural resource declines. Agriculture uses 70% of all freshwater resources globally, and the use of chemicals, pesticides, and herbicides also pollutes waterways. In addition, agriculture production is one of the main contributors to biodiversity loss, particularly from forestscapes. According to the Science Panel for the Amazon,[10] 17% of the Amazon has been deforested, with nearly all of that (14%) converted into agricultural land. Such deforestation is one of the primary threats to biodiversity in the region, with projections that climate change and deforestation combined could lead tree richness to decline by 58% by 2050.

Diets overall have impacts on both human health outcomes and environmental sustainability. Dietary quality and other factors contribute to the growing burden of all forms of malnutrition: undernutrition (stunting, wasting, and underweight), micronutrient deficiencies, overweight and obesity, and non-communicable diseases. While food supplies have been able to adapt to rapid global dynamics and changes, food systems are showing some strain. For example, food supplies have, in general, been able to provide enough calories and diversity to meet the rising demand for animal-source foods, fruits, vegetables, legumes, and the range of processed food products that dominate grocery store shelves. These processed foods, called ultra-processed foods, are however devoid of nutrients but with excess sugar, salt, saturated fats, and additives. These foods, along with shifts from whole grains rich in fiber to refined carbohydrates, are of great concern for nutrition and health outcomes.

9 World Health Organization. (2024, March 1). Obesity and overweight. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

10 Science Panel for the Amazon. (2021). Impacts of deforestation and climate change on biodiversity, ecological processes, and environmental adaptation. In Amazon Assessment Report 2021 (pp. 1–3). United Nations Sustainable Development Solutions Network. https://doi.org/10.55161/VKMN1905.

In addition, the demand for animal-source foods has risen. Between 1990 and 2015, the global supply of animal-source foods increased by more than 60%, keeping up with global demand. Animal-source foods have become a scientific and political impasse, with divergent interpretations of the scientific literature and intractable value judgments concerning their consumption for human and planetary health. Producing animal-source foods can tax land, biodiversity, and water resources and drive rising greenhouse gas emissions. To lessen the impact of these foods on the environment and climate, some experts within the nutrition and climate science community suggest that we can meet global nutrient requirements from a highly plant-based diet containing just 14% of calories from animal-source foods, much less than the amount of animal-source foods consumed in a typical North American diet (~30%). Moreover, excess consumption of saturated fat, red meat, and processed meat can increase the risk for non-communicable diseases such as cardiovascular disease, diabetes, and some forms of cancer.[11] Limiting the consumption of these foods, particularly those associated with disease risk, has potential benefits for both human and planetary health.

There is increasing evidence that while these animal-source foods contain high amounts of protein and critical micronutrients needed for human growth, development, and overall health, excessive intake of red meat and processed meats specifically has detrimental impacts on health outcomes.

However, others underline that limiting animal-source foods may not provide all the necessary nutrients for human health, particularly calcium, iron, vitamin B12, and zinc. They indicate that minimizing the consumption of these nutrient-dense foods among key populations could be detrimental to growth, development, and health, particularly in poverty-stricken environments in which the milieu of infectious disease burden on individuals is taxing on physiological systems.

Nevertheless, we must recognize how difficult it will be to fulfill the nutritional needs of 10 billion people living on the planet. Massive injustices and inequities exist in people's ability to access healthy diets. Land-use conflicts, many of which are driven by deforestation and agricultural development, also contribute to such inequities and injustices. Land-use conflict contributes to the food insecurity seen in Nigeria through the impacts of violence, forced migration, and agricultural investment decisions, among others.[12] With the current business-as-usual response to climate mitigation and continued environmental and natural resource constraints and degradation, raising animals and growing foods to feed them will become even more complex, exacerbating inequities in who gets access to what types of foods, when, and through what means.

11 Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., ... & Murray, C. J. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet, 393(10170), 447-492.

12 Olanrewaju, O., & Balana, B. B. (2023). Conflict-induced shocks and household food security in Nigeria. Sustainability, 15(6), 5057. https://doi.org/10.3390/su15065057.

FOOD SYSTEMS ARE SOLUTIONS

While food systems are both instigators and victims of climate change, they are also part of the solution for mitigation and adaptation. A range of supply-side macro- to micro-level policies and interventions can be adopted, adapted, and scaled across agriculture landscapes and food supply chains. There are a host of demand-driven solutions that policymakers and the private sector can implement to assist consumers in making healthy and sustainable dietary choices.

Nutrition resilience can be achieved by improving food productivity and minimizing food loss, reducing GHG emissions from agriculture, and implementing adaptation strategies for those who are nutritionally vulnerable. As shown in **Figure 2**, these measures span agriculture inputs, as well as the availability of, access to, and utilization of food. Specific actions that can increase the resilience of food systems and households to climate change include research and development of stress-tolerant and resilient crop varieties and animal breeds, more efficient food markets, agricultural information services, improved social protection measures, and early-warning systems.

Figure 2: Climate-resilient strategies across food systems

Theme	Action
1. Food supply-chain inputs	Increase access to seed varieties and livestock breeds that are diverse and resilient to variable weather conditions (heat and drought), pests, and diseases.
	Use agricultural extension programs to improve access to information and training about these varieties and breeds.
	Improve soil quality through the use of cover crops, crop rotation, balanced use of fertilizers, and manure.
	Increase irrigation systems to protect crops and livestock from loss due to changes in seasonal precipitation and extreme weather events.
2. Agriculture production	Invest in and provide education on integrated land-use policies and mixed crop and livestock systems.
	Expand access to services and financing to support farmers, including farmer risk-management tools, insurance, and loans.
3. Post-harvest storage and processing	Improve infrastructure, especially in rural areas, including roads, warehouses, and processing plants.
	Provide training on safe storage and processing techniques, such as drying.
4. Distribution, marketing, and retail	Improve retailer access to water, electricity, and cold storage.
	Create networks of food producers to increase market access and help limit food waste.
	Improve transportation infrastructure in areas where the effects of climate change will limit people's ability to access markets.
5. Food consumption and utilization	Expand access to social protection services, including unconditional cash transfers and supplementary food allowances.
	Increase consumption of animal-source foods in low- and middle-income countries while educating the public about the health risks associated with the overconsumption of these foods.
	Improve access to safe and energy-efficient cookstoves.
6. Undernutrition	Increase access to healthcare for vulnerable populations, especially the rural poor, by increasing healthcare facilities and staff.
	Provide access to animal-source and fortified foods for nutritionally vulnerable populations.
7. Early warning systems	Improve early warning systems and increase farmers' access to them.
	Provide training to producers on how to protect crops, store food, and otherwise prepare for extreme weather events.
8. Evidence for and inclusion of nutrition in climate research	Conduct research and collect and analyze data on how climate change affects the food system and how to maximize nutrition amid these effects.

Source : Fanzo, J., Davis, C., McLaren, R., & Choufani, J. (2018). The effect of climate change across food systems: Implications for nutrition outcomes. Global Food Security, 18, 12-19.

Agriculture production practices can be a source of mitigation potential. Depending on the system – be it crops, livestock, or aquaculture – there are a range of solutions such as precision agriculture (using GPS or drones to optimize the use of fertilizers and pesticides, etc.), crop rotation and diversification, conservation tillage to reduce soil disturbance and erosion, agroforestry, and cover cropping. Solutions also include sustainable livestock management such as improved feeds, rotational grazing, and vaccines to reduce methane emissions. Uruguay, which is a significant livestock producer and where agriculture is a major contributor to the country's total GHG emissions, has introduced measures to support improved management of livestock in grasslands.[13] While all these solutions have their strengths and weaknesses, there needs to be robust policies and an enabling political environment to make these changes and facilitate and assist farmers through them so they can adapt without significant risk.

"However, with the high cost of nutrient-rich foods and overall diets, climate change, and food inflation worldwide, safety nets and other social protection measures are needed for resource-constrained households and vulnerable and marginalized individuals."

To ensure supply chains are resilient, there is a need to invest in improved technologies and practices for storing food and reducing post-harvest loss. There must also be more innovation and technology in cold-chain storage to ensure food is not spoiled, lost, or wasted in transport and storage. Establishing early-warning systems and climate information services is critical to enable farmers and others working in food systems to incorporate climate and weather information and analyses into their decision-making.

13 Food and Agriculture Organization of the United Nations. Reducing emissions intensity and improving natural resources management through livestock in natural grasslands in Uruguay. 2020.

Various policies and strategies are also available to incentivize consumers to shift their diets towards healthier and more environmentally sustainable ones. However, with the high cost of nutrient-rich foods and overall diets, climate change, and food inflation worldwide, safety nets and other social protection measures are needed for resource-constrained households and vulnerable and marginalized individuals. The affordability of low-cost healthy items is essential, but more is required to ensure access to and consumption of healthy diets.

For those who have more choice, there are ways to help guide populations towards healthier and more sustainable food choices, including providing health and environmental information and declarations on food product packaging and instituting national food-based dietary guidelines to guide public procurement, such as school meal programs.

CONCLUSION

It is increasingly recognized that food is central to the climate agenda and that moving towards more sustainable food systems that produce healthy diets is a pathway to climate mitigation and adaptation. However, the opportunity to mitigate climate change is closing, and food systems' action and investment must be scaled rapidly.

To ensure food systems are climate resilient and able to produce healthy diets for everyone in equitable ways, a range of actors working at different scales – from local to global – need to participate in the transformation. However, the latter will have its fair share of trade-offs. Policymakers are often in the dark about how these will materialize and how food systems perform under duress, leaving them uncertain of where to intervene and invest.

To deal with these trade-offs and better guide policymakers, the research community needs to provide rigorous data and evidence to unpack some of the most complex food issues in real-time and translate those findings to decision-makers across food systems. The challenges and opportunities for food systems data and science that lay ahead are significant, requiring that high-quality science be translated into policy faster than ever before.

Yet, data is not enough. We need more political will and commitment to food systems actions to tackle the climate crisis. Integrating food commitments and investments into the Conference of Parties climate meetings and committing to food systems transformation will be of the utmost importance in the next few years if we want to achieve both human and planetary health.


RED FLAM
WONDER
LAND