

CHAPTER 11

Climate Change Risks for Agriculture, Health, and Nutrition



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Summary The stability of global, national, and local food systems is at risk under climate change. Climate change affects food production, availability of and access to food, food quality, food safety, diet quality, and thus people's nutrition and health. Climate change may further slow progress towards a world with food security for all. Climate change impacts will exacerbate food shortages, especially in areas that already show a high prevalence of food insecurity. Climate change will affect good nutrition through complex indirect pathways, such as income shocks when droughts or floods occur, loss of employment opportunities, health effects resulting from air pollution and changed water systems. A conceptual framework for a food systems analysis is presented here, and the linkages within the system and expected changes among them are elaborated—some on a global scale and some on a micro scale. Policy actions are proposed and research gaps are identified.

Introduction

The global food system is malfunctioning, leaving large segments of the population undernourished or malnourished and causing large environmental damage. Climate change adds to the challenge. Climate change and agriculture are in a reciprocal relationship: Greenhouse gas emissions related to land use and animal production make agriculture an important cause of climate change. In turn, climate change and its related extreme events affect agriculture and the food system through changing production conditions and complex environmental and economic externalities, some of which have serious impacts on human health and nutrition.

It is well understood that food security has strong linkages to agriculture with its multiple functions for economy, ecology, and people's livelihoods. The more spe-

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cific linkages between agriculture, food security, health, and nutrition have received more research attention recently (Fan & Pandya-Lorch, 2012; von Braun, Ruel, & Gillespie, 2012). However, further research is needed as the complex linkages between food security and health are dynamic in the context of global change processes, including climate change, urbanization, and market integration (Ruddiman, Ellis, Kaplan, & Fuller, 2015). The linkages are not easily quantifiable which, however, does not imply they are weak (Masset, Haddad, Cornelius, & Isaza-Castro, 2012; Webb & Kennedy, 2014).

The focus of this chapter lies on some of these linkages in particular, with an emphasis on additional risks for agriculture, food security, and related nutrition and health problems emerging from climate change. Climate change may slow down progress towards a world with food security for all. The stability of whole food systems may be at risk under climate change, through shocks and increased variability in markets. On a global scale, a pattern of the impacts of climate change on crop productivity, and thereby on food availability, emerges. Unless public policy actions are taken, these climate change impacts will exacerbate food shortages, especially in areas that already show a high prevalence of food insecurity. Climate change will also affect access to food and high-quality nutrition through indirect pathways such as income shocks, when droughts or floods occur, burden on (women's) time use, and loss of employment opportunities. Health effects are caused by air pollution (indoor and outside) and possibly through changed water systems.

In view of the complex links through which climate change may have an impact on global food security, a food systems approach is needed. A conceptual framework for a food systems analysis is presented first, then linkages within the system and expected changes among them are elaborated—some on a global scale and some (if widely prevalent) on a micro scale. Finally, policy actions are proposed and research gaps that warrant our attention are identified.

Conceptual Relationships of Agriculture, Food Security, and Health Under Climate Change

Agriculture is inherently sensitive to climate variability and change, whether due to natural causes or human activities. Climate change due to emissions of greenhouse gases is expected to directly impact crop production systems for food, feed, or fodder; to affect livestock health; and to alter the pattern and balance of trade of food and food products. These impacts will vary with the degree of warming and associated changes in rainfall patterns, and from one location to another, but underpinning these impacts are a number of direct effects on the physiology of crops grown for food, feed, fuel, and fiber as well as on the pests and diseases of livestock and crops.

A conceptual framework is put forward here. The concept takes a broad perspective on agriculture, comprising crops, animal production, and connected value chains as well as the natural resource base of land and water use, and the technological

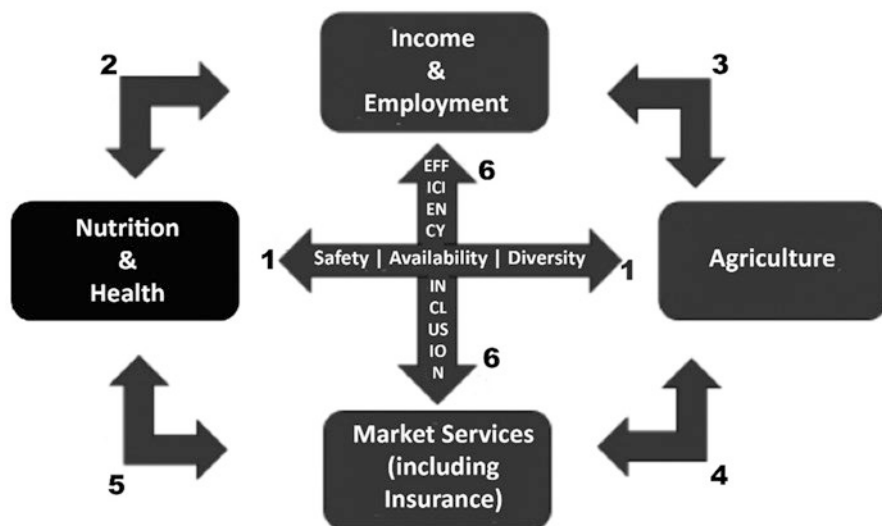


Fig. 11.1 Conceptual framework—a food systems perspective (Adapted from von Braun, 2017)

foundations of agriculture. Institutions, information, and behavior are interdependent issues that influence linkages in all of the domains that describe the framework. The linkages of food security and agriculture with health can be broadly grouped into six domains as depicted in Fig. 11.1, and all of these are influenced by climate change in various ways:

Link 1: Agricultural production- and processing-related health linkages are central, especially in the long run. They entail, for example, diet-, nutrition-, and health-sensitive agriculture, paying attention to food supply and access to nutrients with diverse diets, quality and safety of foods, and production conditions (Pontifical Academy of Sciences and Global Alliance for Improved Nutrition, 2018). To the extent that climate risks add instability in production, the direct and indirect linkages to food security and health are adversely impacted. Technology is critical for these links.

Links 2 and 3: Income- and employment-related linkages greatly determine access to nutrition and health, especially by marginal farm households and agricultural laborers (Gatzweiler & von Braun, 2016). If, under a climate shock, rural labor markets contract for services and landless laborers, there may be adverse implications for health and nutrition. For instance, health services may become unaffordable and often school fees are no longer paid. Agriculture and income and employment links are fundamental for onward linkages to nutrition.

Links 4, 5, and 6: Linkages with markets and services drive nutrition and health via income, but also directly via food price formation and forward and backward market linkages. If services and infrastructures are malfunctioning under climate stress, the adverse impacts of climate change increase. Markets and services are

critical for delivering affordable nutritious food as well as nutrition and health-related services. Under increased climate risks, investments in health and nutrition services will need to expand to enhance the adaptation capacities of the poor. Efficiency of markets and inclusive services with insurance mechanisms are key forces behind income and employment generation and households' capacity to deal with risks and shocks. This, in turn, drives many aforementioned linkages.

Like any framework, simplifications and abstractions are implicit in order to focus on key causal linkages. The linkages include various *feedbacks among them*, such as from health to production through impaired labor productivity (which may, for instance, be adversely affected by stress from heat waves), and from markets to income through prices and consumption effects. Overarching, and surrounding Fig. 11.1, are *agricultural and environmental as well as macroeconomic framework conditions*. Related linkages exist on a global scale, such as links related to greenhouse gas emissions and, on a local scale, water and sanitation in the context of irrigated agriculture. All the links operate with *diverse dynamics under short- or long-term time lags*, which require attention in policies and programs. This outlined framework also demonstrates the need for attention to the complex causal linkages and behavior change in food systems that need to be considered in modelling climate change impacts on populations and wellbeing. Neglecting these linkages and indirect effects may over- or underestimate climate change threats for people.

The following sections of the chapter address selected components of the framework in which food security, agriculture, and health/nutrition linkages may be affected by climate change.

Climate Risks for the Stability of the Entire Global Food System

Before reviewing key linkages within the food system, the system as a whole is considered because the stability of whole food systems may be at risk under climate change. Important issues here are extreme events, especially in production, crop and animal pests, and markets. Climate change is likely to increase food market volatility from the production and supply side. Demand-side shocks are also possible in a political economy context, such as in the case of aggressive bio-energy subsidies and quota policies. Policy shifts of the last decade in the USA and EU were partly motivated by energy security and partly by climate mitigation objectives. The resulting destabilization effects in food markets, which contributed to large food security problems, were therefore partly related to climate change policies. Climate change may be one trigger of effects for broader destabilizations of food security, including the risk of *high and volatile food prices*, which temporarily limit poor people's food consumption (Kalkuhl, Braun, & Torero, 2016); *financial and economic shocks*, which lead to job loss and credit constraints; and the risks that *political disruptions and failed political systems* pose for food security, such as conflicts over land and

water, which are increasing under climate change. These complex system risks can assume a variety of patterns and can become high-risk combinations.

Landmark studies on climate change and agriculture since 1994 include those by Parry, Rosenzweig, Iglesias, Livermore, and Fischer (2004), Cline (2007), and the World Bank (2010). These studies focus mainly on production effects and, in some cases, on the expected changes of average prices. More recent studies highlight the roles of mitigation and adaptation interventions for the reduction of climate change impacts (Richardson, Lewis, Wiltshire, & Hanlon, 2018). Baldos and Hertel (2015) quantify the crucial role of a well-functioning global trade system for the reduction of climate change impacts on food security. Extreme weather events need to be considered in comprehensive climate change impact analyses (Lesk, Rowhani, & Ramankutty, 2016). In a recent global modelling study, this is embedded in the determinants of risks for global crop production for maize, wheat, rice, and soybeans over the period 1961–2013 (Haile, Wossen, Tesfaye, & von Braun, 2017). Using seasonal production data, price change and price volatility information at the country level, as well as future climate data from 32 global circulation models, it is projected that climate change could reduce global crop production by 9% in the 2030s and by 23% in the 2050s. Climate change is expected to lead to 1–3% higher annual fluctuations of global crop production over the next four decades. Furthermore, Haile et al. (2017) found:

- A strong, positive and statistically significant supply response to changing prices for all four crops. However, output price volatility, which signals risk to producers, reduces the supply of these key global agricultural staple crops—especially for wheat and maize.
- Climate change has significant adverse effects on production of the world’s key staple crops.
- In particular, weather extremes—in terms of shocks in both temperature and precipitation—during crop growing months have detrimental impacts on the production of the abovementioned crops. Weather extremes also exacerbate the year-to-year fluctuations of food availability, and thus may further increase price volatility with its adverse impacts on production and poor consumers.

The inclusion of volatility in the production and price developments (i.e., the inclusion of risks associated with climate change) is the new aspect of this research, which gives further insights. Combating climate change using both mitigation and adaptation technologies is crucial for global production and hence food security on a global scale. The projected effects of climate change on production (Fig. 11.2) use the national climate data from country specific GCMs as forecasts with national resolution to capture the heterogeneity of future climate change in the study countries. The climate change impacts are more severe in the 2050s. Future climate change also increases the risk associated with crop production: climate change increases the variance of crop production by 1.4% and 2.8% in the 2030s and 2050s, respectively.

Projected average crop production shows positive but small changes for countries such as the Russian Federation, Turkey, and Ukraine in the 2030s, whereas production changes are negative and more pronounced for all countries in the 2050s.

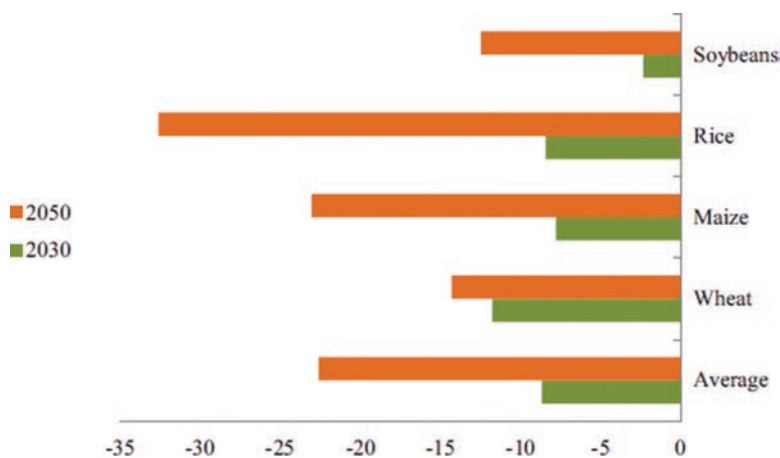


Fig. 11.2 Projected effect of climate change on food production (%) (Source: Haile et al., 2017)

These effects on the climate-induced average food production changes have significant implications for global food security for two reasons: (1) wheat, rice, maize, and soybeans make up about three-quarters of the food calories of the global population; (2) our study countries produce more than 85% of the global production of these crops. Technological advances for sustainable production systems and trade for balancing regional and local deficits may need to expand to cope with the risks for food security.

Functioning agricultural markets are important for access to food and services and, thereby, also for income and health (Kalkuhl et al., 2016). However, volatility in prices, even in efficiently functioning markets, may adversely impact consumption capabilities and health. Price volatility is not a new phenomenon, though some of its causes are. Several studies (e.g., Abbott, Hurt, & Tyner, 2011) have identified the drivers of price upsurges, such as biofuel demand, speculation on future commodity markets, public stockholding, trade restrictions, macroeconomic shocks to money supply, exchange rates, and economic growth. Tadesse, Algieri, Kahkuhl, and von Braun (2014) found that a food crisis is more closely related to extreme price spikes, whereas long-term volatility is more strongly aligned with general price risks. In 2007–2008, the prices for almost all food commodities increased significantly, inducing negative effects especially for low-income countries and the part of their population that spends the biggest share of their income on staple foods. To the extent to which climate shocks result in price spikes, health and nutrition consequences can be serious for the poor (Kalkuhl et al., 2016).

Large parts of the world, where negative impacts of climate change on crop production are expected, coincide with countries that currently have high levels of food insecurity. There is a robust and coherent pattern at the global scale of the impacts of climate change on crop productivity, and most likely on food availability. These impacts will exacerbate food insecurity in areas that currently show

Impacts of climate change on the productivity of food crops in 2050

Sources: World Bank Publishers
World bank Development report 2010
<http://wdonline.worldbank.org/>

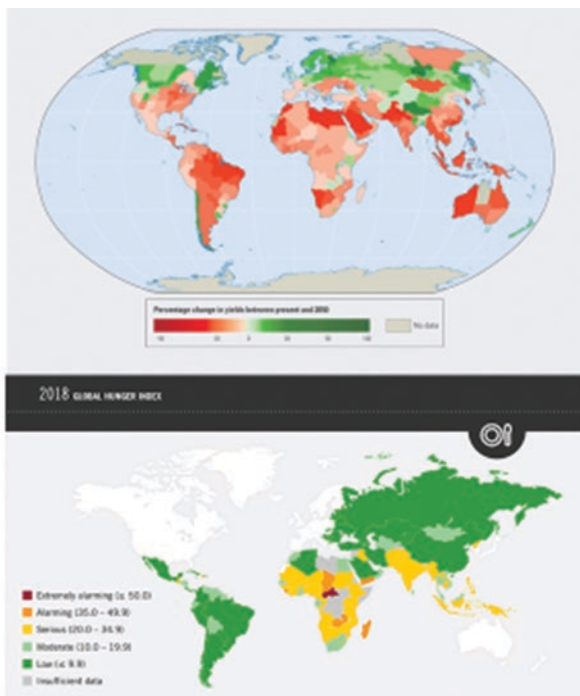


Fig. 11.3 Climate variability and change, and food security (Sources: see inside the figure)

a high prevalence of hunger (Fig. 11.3) as identified by the Global Hunger Index (Welthungerhilfe and Concern International, 2018).

Agricultural Production- and Processing-Related Health Linkages Under Climate Stress

Utilization of food depends much upon behavior and the health environment (including water and sanitation), so any impact of climate change on the health environment also affects this dimension of and pathway toward food security. Research on these links and climate change is rather weak, but some meaningful extrapolations can be derived from related research (Wheeler & von Braun, 2013):

- Links with drinking water may be the most obvious when climate variability further strains clean drinking water availability. Hygiene may be equally affected by extreme weather events (e.g., floods) in environments where sound sanitation is absent.
- Additionally, the uptake of micronutrients is affected negatively by diarrheal diseases, which strongly correlate with temperature.

- Other pathways from climate change to nutrition potentially work through risks from climate change for diet quality or, for example, increased storage costs and pest attacks that may result from ecological shifts.

This brings out the importance of non-food inputs in food security, including infrastructure and health services for adaptation and coping. While problems of insufficient and poor-quality food persist, global changes are creating new nutritional issues such as the “nutrition transition”—a process by which urbanization and changes in lifestyle are linked to excess caloric intake, poor-quality diets, and low physical activity, which together lead to rapid rises in obesity and chronic diseases, even among the poor in developing countries. The nutrition transition will unfold in parallel with the climate change process in coming decades. Very little research on the potentially re-enforcing effects of the two has been conducted.

As pointed out in the framework above, agriculture-related health linkages are direct through availability and indirect via income-related effects. In particular, rural populations in low- and middle-income countries are significantly influenced by the linkages between agriculture and health, as their economies are often highly dependent on agriculture as a major provider of employment and income. Direct agricultural production–health linkages need to take into account that the majority of the world’s poor live on small farms. There are about 570 million farms worldwide, the majority of which are very small and located in China, India, and Africa (von Braun & Mirzabaev, 2015). Improving the productivity and incomes of smallholder farmers can help significantly to reduce poverty. There are several ways how this can be achieved. First, commercialization and technological innovations among smallholders can help reduce poverty (Gatzweiler & von Braun, 2016).

Diversification from solely staple crop production to the production of commercially high-value crops is another avenue for reducing poverty among smallholders. Diversification typically may also involve specialization at the farm level, with growing variety of production and processing at the regional level. Efficient storage and food processing plants are as important as improving agricultural systems to provide a diverse and safe diet (Keding, Schneider, & Jordan, 2013).

Part of the solution is nutrition-sensitive agriculture, which focuses on the causes of malnutrition and is more long-term oriented (Balz, Heil, & Jordan, 2015). The approach encourages production and consumption of a variety of foods, recognizes and emphasizes the nutritional value of food, and considers the significance of food production for the agricultural sector as well as for rural livelihoods (Thompson & Amoroso, 2014). The provision of information for consumers is essential to the success of this kind of intervention.

A host of studies are now available on communities and households on the micro-level being exposed to climate shocks. These approaches tend to capture more adaptation capabilities than macro-models, such as assets draw down, job-switching migration, social policy responses, and collective action, as shown in detail by Rakib and Matz (2016) for rural Bangladesh. These studies should be a basis to expand analyses into health effects. Taken together, macro modeling and micro-level analyses of climate change linkages to food security are complementary.

Income- and Employment-Related Linkages of Climate Change

Food access and utilization of foods may be impacted by climate change through indirect but rather strong pathways. Access to food is largely a matter of household and individual-level income, of capabilities and rights as well as of behaviors. Food access issues have been studied through two types of approaches: top-down by models that attempt to link macro-shocks related to climate change to responses and adaptation outcomes (Nelson et al., 2010; van Meijl et al., 2018); and by community- and household-level studies that try to assess climate change effects bottom-up. Specific findings of top-down approaches are heavily dependent on the assumptions made about future income and population growth, but in general clear linkages between economic growth and resilience to climate change can be shown. Springmann et al. (2016) modelled the relationships between climate change, diet change, and related health outcomes at the global scale and found adverse health effects.

Agricultural practices can also be the source of health hazards through the use of toxic substances, such as pesticides and fertilizers. Mycotoxins are another case in point, which evolve, for example, due to improper crop handling or use of inferior seeds (Smith, Stoltzfus, & Prendergast, 2012). More unpredictable flooding and strong rains are likely to increase the risks of mycotoxins.

In addition, there are several foodborne diseases that can occur through the mis-handling of agricultural products. For this reason, effective food safety schemes are just as important to promote health as are policies to reduce food insecurity (Pontifical Academy of Sciences and Global Alliance for Improved Nutrition, 2018). Heat waves make food handling more difficult in low-income countries. Cold chains may in the long run become more accessible for the poor due to decentralized (solar) energy systems, but that is still in a distant future for many low-income rural households. Facilitating access to safe foods by such means as cold chains should increasingly be considered a matter of public health investment, rather than consumer subsidies.

Linkages of Climate Change and Health via Markets and Services

A particularly complex set of agriculture-health linkages lies within the broader ecological and public health context of farming communities. An important subset of these is the environmental health linkages of partly agriculture-related water quality and quantity problems interacting with farm populations' sanitation and hygiene behaviors. The importance of water quality for health is well known. The impact of agriculture on both the water quality and quantity with respect to health issues, though, is not well researched. The health costs of sanitation and water prob-

lems are large. In addition, in peri-urban settings, farmers often have neither the choice to use other water than wastewater for irrigation, nor do they have the knowledge on the potential risks related to that resource (Qadir et al., 2010)—including harm for human health and the environment through the introduction of pathogens or contamination with chemical substances. There is also a clear linkage between these health, environmental, and behavioral issues on the one hand and the nutritional status and farming on the other hand (Usman, Gerber, & Braun, 2018).

The Water-Energy-Food Security Nexus surrounds the energy decision-making process of rural households. The rural energy system and its impacts on environment, agriculture and health are connected in complex ways to climate change. Attention is drawn here to just one of the complex relationships: The majority of rural households in developing countries continue to depend on unreliable, inefficient, and harmful household energy technologies. As a consequence, many of the poorest people are exposed to household indoor air pollution from cooking and heating with dirty energy and inappropriate technology. This results in large mortality and disease rates, mainly among children and women of poor households who cook and spend more time indoors than men (Smith et al., 2014). The problem is old, but it may change further with increased climate risks. The link to climate and environmental change is indirect but can be particularly strong for the poor, as it is often based on collected fuel wood (mainly by women), cow dung cakes (South Asia), and charcoal, with adverse effects on ecologies. Women's time allocation for energy production (such as fuel wood collection or producing dung cakes), for food and for home goods production is a critical element of the linkages. When, for instance, distance to collectable fuel wood increases due to deforestation and land-use change—both being important forces of greenhouse gas emissions—women's time investments for collecting fuel wood increases, which may come at the cost of sustainable local food systems. Development of village energy systems (e.g., solar or bio-based) is important to facilitate the needed cooking, lighting, power, and irrigation of the village community in sustainable ways, and this cannot be achieved by individual household initiatives. Also, clean cooking stoves fit financially, technically, and according to the perceptions of communities, have a potential to reduce the adverse health effects of indoor pollution from smoke in low-income communities in rural areas.

Policy Implications and Research Challenges

Action needs to be taken by policy-makers and practitioners confronted with the prospect of climate change impacts on food security, nutrition, and health primarily regarding these threats:

1. Climate change-related production and price volatilities will increase risks and uncertainties within the global food system, and impact food and nutrition security through food availability and price effects.

2. Climate change impacts on food security as well as related health and nutrition aspects will be worst in countries already suffering from high levels of hunger, and they will aggravate over time. Doing nothing in response to climate change will have potentially large consequences for global undernutrition and malnutrition, and this will worsen over time.
3. Inequalities and locations of food insecurity may change. People and communities who are currently vulnerable to the effects of extreme weather may become more vulnerable in the future, as they are less resilient to climate shocks.

Action needs to be directed towards what could be termed a “climate-smart food system”—not just climate smart agriculture—that addresses climate change impacts on all dimensions of food and nutrition security. Research initiatives need to be part of the action agenda (Campbell et al., 2016). Governance of food systems matters too. Exploiting the positive linkages between agricultural production and health is particularly constrained by intersectoral and disciplinary bias that impedes collaboration (von Braun et al., 2012). A policy study of Africa found that intersectoral collaboration for nutrition is enhanced when there is inclusive programming and jointly agreed-upon and compatible monitoring and evaluation in place (Malabo Montpellier Panel, 2017). Much more of that is needed under increased climate risks. Considerable investment in adaptation and mitigation actions is needed to slow the impacts of climate change on the progress of global hunger. There is a wide range of potential adaptation and resilience options. These need to address food security in its broadest sense and be integrated into the development of agriculture worldwide.

Strengthening agricultural resilience through science, change in technology and production systems is a key part of this. However, it is not sufficient on its own for global food security. The whole food system needs to adjust with strong attention to science-based insights, trade, stocks, nutrition and health, and social policy options, as outlined by the InterAcademy Partnership (2018). Related priorities for research include:

1. Climate change impacts on food access, nutrition, and health should be more comprehensively considered.
2. Much of the climate change impacts on food security are rather indirect, but that does not mean they are small. Understanding these indirect impacts requires more comprehensive analytical approaches and sophisticated modelling, including their political economy linkages.
3. Better integration of research on the human dimensions, including understanding behavior and collective actions, together with biophysical changes will be central to understanding and identifying policy options in support of food security and healthy living under climate change-related risks.

Important is the strengthening of data basis and monitoring. The “Lancet Countdown” aims to track the health impacts of climate hazards; health resilience and adaptation; health co-benefits of climate change mitigation; economics and finance; and political and broader engagement (Watts et al., 2017). This could also strengthen capacities to integrate health in climate modelling.

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