

Climate change and nutrition: Creating a climate for nutrition security

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Abstract

Background: Climate change further exacerbates the enormous existing burden of undernutrition. It affects food and nutrition security and undermines current efforts to reduce hunger and promote nutrition. Undernutrition in turn undermines climate resilience and the coping strategies of vulnerable populations.

Objectives: The objectives of this paper are to identify and undertake a cross-sectoral analysis of the impacts of climate change on nutrition security and the existing mechanisms, strategies, and policies to address them.

Methods: A cross-sectoral analysis of the impacts of climate change on nutrition security and the mechanisms and policies to address them was guided by an analytical framework focused on the three 'underlying causes' of undernutrition: 1) household food access, 2) maternal and child care and feeding practices, 3) environmental health and health access. The analytical framework includes the interactions of the three underlying causes of undernutrition with climate change, vulnerability, adaptation and mitigation.

Results: Within broad efforts on climate change mitigation and adaptation and climate-resilient development, a combination of nutrition-sensitive adaptation and mitigation measures, climate-resilient and

nutrition-sensitive agricultural development, social protection, improved maternal and child care and health, nutrition-sensitive risk reduction and management, community development measures, nutrition-smart investments, increased policy coherence, and institutional and cross-sectoral collaboration are proposed as a means to address the impacts of climate change to food and nutrition security. This paper proposes policy directions to address nutrition in the climate change agenda and recommendations for consideration by the UN Framework Convention on Climate Change (UNFCCC).

Conclusions: Nutrition and health stakeholders need to be engaged in key climate change adaptation and mitigation initiatives, including science-based assessment by the Intergovernmental Panel on Climate Change (IPCC), and policies and actions formulated by the UN Framework Convention on Climate Change (UNFCCC). Improved multi-sectoral coordination and political will is required to integrate nutrition-sensitive actions into climate-resilient sustainable development efforts in the UNFCCC work and in the post 2015 development agenda. Placing human rights at the center of strategies to mitigate and adapt to the impacts of climate change and international solidarity is essential to advance sustainable development and to create a climate for nutrition security.

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Undernutrition remains one of the world's most serious but least addressed socioeconomic and health problems [1–3], hitting the poorest the hardest, especially women and children. The number of people suffering from hunger stood at 925 million in 2010, and maternal and child undernutrition persists [2, 4]. In developing countries, nearly one-third of children are underweight or stunted, and undernutrition is the cause of more than one-third of deaths among children under 5 years of age [1, 3, 4]. Undernutrition, including

micronutrient deficiencies, also referred to as “hidden hunger,” is caused by inadequate dietary intake and disease, which in turn stem from food insecurity, poor maternal and child care practices, and inadequate access to clean drinking water and safe food, sanitation, and quality health services. The human and socioeconomic costs of undernutrition are enormous, falling hardest on the poorest, especially on women and children [1, 3]. Undernutrition interacts with infectious disease, causing an estimated 3.5 million preventable maternal and child deaths annually [3, 4]. The millions of people who have experienced undernutrition early in life tend to face many challenges as they grow up [5]. They encounter increased risks of illness, experience difficulties at school, and are often not able to make a full contribution to the social and economic development of their households, communities, and nations when they become adults [5]. Undernutrition during the critical stages of fetal development and early childhood is very often the beginning of a vicious cycle of negative feedbacks, leading very often to social and economic vulnerabilities later in life, particularly in women, which then perpetuate undernutrition in the next generation. The resulting impacts in terms of lost national productivity and economic growth are huge. Recent food and economic crises and economic downturn have magnified the problems [1, 3, 6]. International and national nutrition stakeholders are now stepping up to address this urgent challenge, including through building up a global movement for Scaling Up Nutrition (SUN) actions at the country level [3].

Climate change affects food and nutrition security and progress made to date, and undermines current efforts to reduce hunger and protect and promote nutrition [7–16].

Undernutrition in turn undermines the resilience to climatic shocks and the coping strategies of vulnerable populations, lessening their capacities to resist and adapt to the consequences of climate change.

Despite this, nutrition stakeholders are largely disconnected from key climate change discussions. Although safeguarding food production is part of the ultimate objective of the UN Framework Convention on Climate Change (UNFCCC), the topic of nutrition remained absent from the agreements reached by the Conference of the Parties of the UNFCCC Ad Hoc Working Group on Long Cooperative Action (AWG-LCA) during the last sessions [17]. This lack of consideration of nutrition security in climate change negotiations is alarming.

This paper analyzes the pathways through which climate change is exacerbating the existing unacceptable levels of hunger and undernutrition and indicates some concrete policy directions to address nutrition security through the current climate change-related initiatives. It has been developed by a group of concerned

scientists and stakeholders working under the auspices of the United Nations System Standing Committee on Nutrition (UNSCN) [18]. Most of these stakeholders are engaged in the SUN movement [3].

The triple crisis of 2008—food prices, fuel prices, and financial sector—drew global attention to the plight of almost 1 billion people who were still suffering, in 2011, from food insecurity and who were at risk for or already suffering from undernutrition. As a result, there is increased recognition of the fact that if the Millennium Development Goals are to be achieved, undernutrition must be tackled at scale, particularly among the most vulnerable women and young children. **Box 1** clarifies the definition of key terms used in the frame of this paper: malnutrition, undernutrition, hunger, food security, nutrition security, and sustainable diets.

Undernutrition and nutrition insecurity, major consequences of climate change that are still poorly addressed by current climate change initiatives

An analysis published by the World Health Organization (WHO) and reviewed in the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report concludes that the negative effects of changing temperatures and precipitation on agricultural production, and therefore on food security and undernutrition in developing countries, constitute the largest single negative impact of climate change on health due to the very large numbers of people that may be affected [8, 22].

Climate change increases the overall risk of hunger and undernutrition [7, 23] and challenges the realization of the human rights to health and adequate food [24, 25]. Climate change is already affecting nutrition security through different causal pathways that impact food security, livelihoods, household food access, maternal and child care, health, water and sanitation, and many socioeconomic factors that determine nutrition security [7–15] (**fig. 1**).

Figure 2 provides a comprehensive overview of how climate extremes, variability, and change influence maternal and child undernutrition and its three key determinants: household food access, maternal and child care and feeding practices, and access to health services and environmental health. These three key determinants are shaped, in turn, by other factors, such as livelihoods, formal and informal institutions, economic, political, and ideological structures, resources, and structural transformations. The distinction between food security and nutrition security is emphasized in this framework.

The poorest and most vulnerable, including women, children, and marginal communities, are at greatest

BOX 1. Key nutrition-related terms used in this paper

Malnutrition is a broad term that refers to all forms of poor nutrition. Malnutrition is caused by a complex array of factors, including dietary inadequacy (deficiencies, excesses, or imbalances in energy, protein, and micronutrients), infections, and sociocultural factors. Malnutrition includes undernutrition as well as overweight and obesity [15, 19]

Undernutrition exists when a combination of insufficient food intake, health, and care conditions results in one or more of the following: underweight for age, short for age (stunted), thin for height (wasted), or functionally deficient in vitamins and/or minerals (micronutrient malnutrition) [15].

Hunger is a term that literally describes a feeling of discomfort from not eating and which has also been used to describe undernourishment, especially in reference to food insecurity [4].

Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life; household food security is the application of this concept to the family level, with individuals within households as the focus of concern [15, 20, 21].

Nutrition security exists when food security is combined with a sanitary environment, adequate health services, and proper care and feeding practices to ensure a healthy life for all household members [15, 19]

Sustainable diets are those with low environmental impacts that contribute to food and nutrition security and to a healthy life for present and future generations. They are protective of biodiversity and ecosystems, culturally acceptable, accessible, economically fair, and affordable. Sustainable diets are nutritionally adequate, safe, and healthy while optimizing human resources [18].

risk for suffering from the potential impacts of climate change [23]. This is due to their high exposure to natural hazards, direct dependence on climate-sensitive resources, and limited capacity to adapt to and cope with climate change impacts [23]. Smallholder and subsistence farmers, pastoralists, and artisanal fisher folk in particular will suffer complex, localized impacts of climate change [7].

Vulnerability to climate change does not exist in isolation from social, political, and economic institutions. Most climate change impact assessments and evaluations are focusing on environmental, economic, and hard infrastructural impacts. However, there is in

addition a wide range of social impacts on people's lives and livelihoods, including effects on health services, social protection systems and redistributive policies, public infrastructure, governance, peace and conflict, accessible and functioning markets, and supports for human mobility. The existence and effectiveness of such institutions determine whether people are affected by climate-related hazards and their ability to confront and recover from negative climate change impacts. Climate change-related extreme events are negatively affecting institutions critical for food and nutrition security, e.g., through physical damage to health infrastructure and overburdening of social services, safety nets, and other social policies, hence multiplying many of the same socioeconomic factors that make people vulnerable to climate change in the first place. With a likely change in the patterns of climate-related extreme events, such as heat waves, droughts, storms, heavy precipitation, and floods [26], and increased risks of disasters [27], vulnerable communities and households will suffer serious setbacks to their food and nutrition security [7, 11, 28].

According to the Emergency Events Database (EM-DAT) of the Centre for Research on the Epidemiology of Disasters (CRED), the number of reported climate-related disasters has more than doubled since the 1980s, affecting over 225 million people annually in the 2000s [29]. It is estimated that 103 million people were affected by drought and 188 million by floods alone in 2010 [29]. In Ethiopia and Kenya, two of the world's most drought-prone countries, studies have found that children aged five or less born during a drought were respectively 36% and 50%

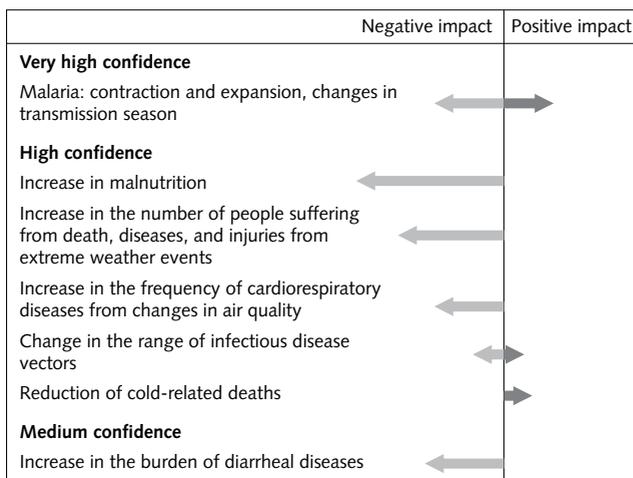


FIG. 1. Direction and magnitude of change of selected health impacts of climate change confidence levels are assigned based on the Intergovernmental Panel on Climate Change (IPCC) guidelines on uncertainty. Source: http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note_ar4.pdf.

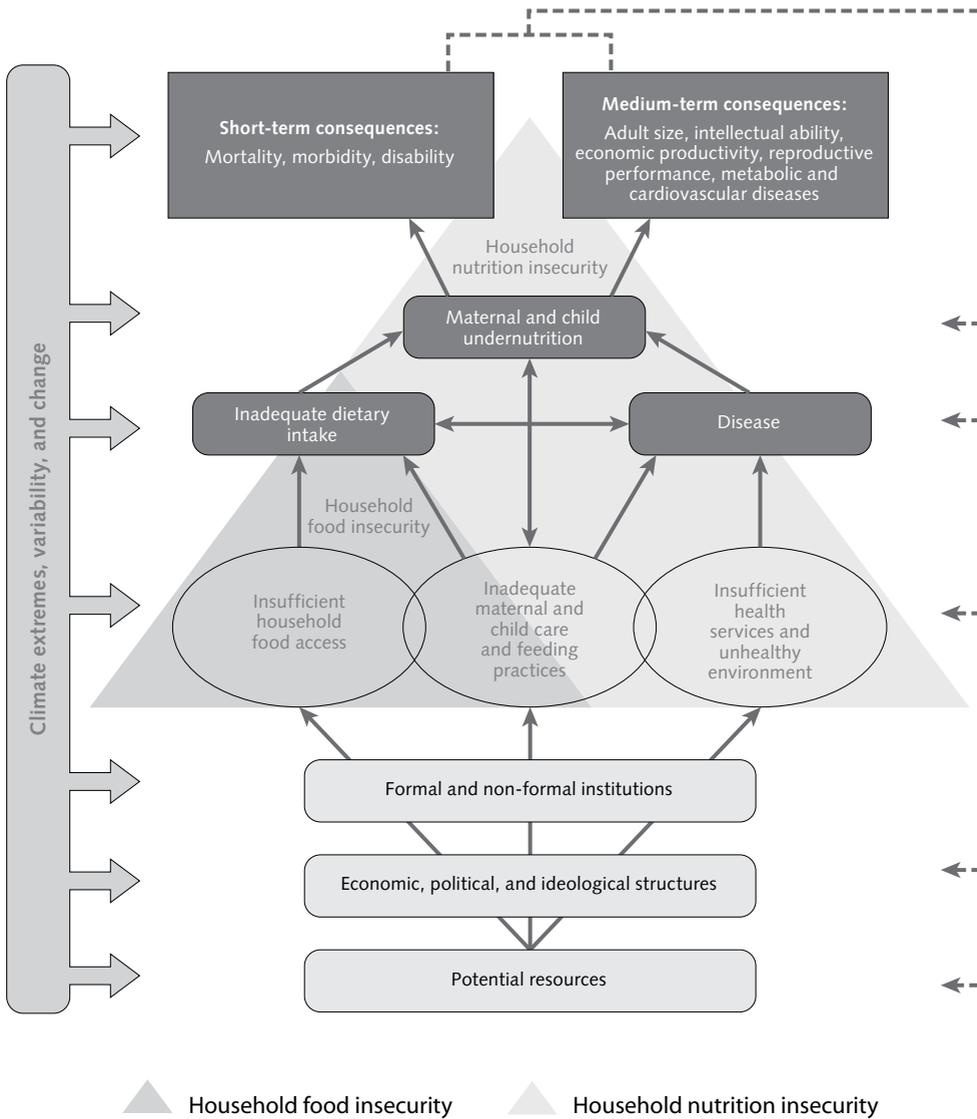


FIG. 2. Framework illustrating the pathways through which climate change affects nutrition

more likely to be malnourished than children not born during a drought [30]. In Niger, children aged two or less born in a drought year were 72% more likely to be stunted [30]. Studies from Bangladesh show that after floods, wasting and stunting rates in the following years increased among preschool children due to reduced access to food, increased difficulties of providing proper care, and greater exposure to contaminants [31]. Climate-related disasters are also a major cause of displacement. More than 38 million people were displaced by climate-related disasters in 2010, losing their livelihoods and their access to nutritious food [32]. The drought in the Horn of Africa that triggered famine in Somalia and spurred food crises in other countries is likely an indication of what may come as such incidents

become more commonplace, with extreme weather events having a higher probability of occurring as a result of climate change.

Despite anticipated increases in the overall range of some agriculturally productive regions, changes in temperature, rainfall, and patterns of extreme events are expected to further reduce food productivity and to make production even more erratic in many vulnerable regions of the world where agricultural productivity is already low, e.g., sub-Saharan countries [7, 14]. With local production declining and probable disruptions caused by climate hazards, income-generating opportunities and purchasing power will decrease for vulnerable populations. At the same time, decreases in production could lead to price increases for staple

crops of 25% to 150% by 2060 [14]. During the present decade, real prices for cereals could average as much as 20% higher than during the decade from 2001 to 2010, with unpredictable weather conditions being the most frequent and significant factor causing price volatility [33]. Other studies project that food prices will more than double in the next 20 years, arguing that half of this increase can be attributed to climate change [34].

According to the IPCC 4th Assessment Report, if current trends continue, it is estimated that 200 million to 600 million more people will suffer from hunger by 2080 [35]. Calorie availability in 2050 is likely to decline throughout the developing world, resulting in an additional 24 million undernourished children, 21% more than in a world with no climate change, almost half of whom would be living in sub-Saharan Africa [10, 14] (fig. 3).

Furthermore, it has been projected that climate change will lead to a relative increase in moderate stunting of 1% to 29% in 2050 compared with a future without climate change [16]. Climate change will have a greater impact on rates of severe stunting, which are estimated to increase by 23% (in central sub-Saharan Africa) to 62% (in South Asia) [16].

In addition to its direct impact on agriculture, food systems, and food security, climate change negatively affects the nutritional value of plant foods. Elevated carbon dioxide results in a reduction in protein concentration in many human plant crops [36–38]. Concentrations of atmospheric carbon dioxide predicted for the next (22nd) century will have major implications for plant physiology and growth and are likely to affect both agricultural production and food quality [36, 37]. Elevated carbon dioxide is likely to have a greater impact on grain protein levels under warmer and drier

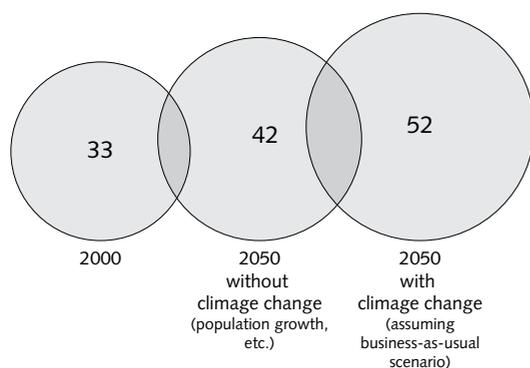


FIG. 3. Number of malnourished children in sub-Saharan Africa (millions). Calorie availability in 2050 is likely to decline throughout the developing world, resulting in an additional 24 million undernourished children, 21% more than in a world with no climate change, almost half of whom would be living in sub-Saharan Africa [10, 14].

Source: Nelson [10]; graphics by World Food Programme

conditions [38].

Climate change can have an impact on environmental health issues such as sanitation; water availability, access, and quality; and the transmission of water-borne, food-borne, vector-borne, and other diseases [8, 39, 40]. Such diseases, in turn, reduce the body's absorption and utilization of essential nutrients, effectively increasing overall nutritional needs. Furthermore, climate change may have negative impacts on occupational health, and thus on the productivity of the agricultural workforce, either directly due to increased worker exposure to heat and extreme weather, or indirectly due to workforce vulnerability to climate-related diseases. As a consequence of the impacts of climate change on nutrition and health, the HIV pandemic is likely to be aggravated, reducing the workforce dedicated to agriculture and to the food supply [41]. This is a great concern, considering that a large proportion of people affected by HIV depend on agriculture for their livelihoods [42]. Climate change can put further strain on the existing heavy workload of women, with negative impacts on their ability to provide proper care to infants and young children, thus further increasing the risk of undernutrition [43, 44].

Even if good progress is made in tackling undernutrition, those efforts could very well be neutralized by climate change if the impacts and threats of climate change to nutrition security are not properly addressed. So far, current climate change-related policies and practices have not considered undernutrition. They consider nutrition insecurity as a "peripheral" issue to the climate change agenda or simply ignore it. In addition, climate change adaptation and mitigation have been addressed separately in the agriculture, food security, social protection, health, and nutrition contexts, when in fact a more integrated approach is needed. There is also mounting evidence that some responses to climate change, such as specific climate change mitigation strategies, are likely to exacerbate food and nutrition insecurity (box 2). This calls for increased coherence between the multiple objectives of food and nutrition security and climate change adaptation and mitigation.

Ensuring nutrition security in a changing climate

Within the broader global efforts on climate change mitigation and adaptation, a combination of nutrition-focused actions supported by research and technological development can reduce the threats to food and nutrition security [11].

A revitalized twin-track approach has been proposed to address the impacts of climate change on food and nutrition security [11, 28]. This approach is aligned with the SUN framework for action. Track 1 consists

BOX 2. Complex challenges for climate change mitigation, agriculture, and nutrition

Climate change mitigation is critical to limit the impact of climate change on food and nutrition security. However, there are mitigation strategies that could also increase food and nutrition insecurity. In particular, the production of certain biofuels can have a negative impact on food production and nutrition of vulnerable groups [11].

Biofuel production requires large amounts of natural resources (arable land, water, labor, etc.) that often are diverted from the cultivation of food crops, or if not, increase pressures on deforestation [11]. Local and global food availability may subsequently be reduced, leading to shortages in markets and associated food price increases [11].

Similarly, the steadily increasing global demand for meat and animal products, particularly in developed countries and in the urban developing world, presents a set of different but equally complex challenges for mitigation, agriculture, and nutrition [45]. Globally, meat production is already a key contributor to agriculture's greenhouse emissions. The livestock sector is the single largest anthropogenic user of the world's ice-free terrestrial surface. The area developed to feed crop production amounts to about 33% of the world's arable land [46]. In 2005, roughly one-third of the world's cereal harvest was fed to livestock [45]. This, in turn, has certain long-term impacts on the availability and price of basic commodities and access to nutritionally diverse food sources [47].

of direct and immediate nutrition interventions, food assistance, and safety nets in response to undernutrition, hunger, and emergencies. Track 2 consists of a broader and longer-term approach that acts to counter the drivers of undernutrition, specifically by promoting agriculture and rural development to improve the availability of, access to, and consumption of nutritious foods by improving social protection and enhancing disaster risk management and by ensuring healthy environments and access to healthcare [23, 28]. It is important to emphasize that all these interventions are important even in a world without climate change, considering that the global crises of hunger and undernutrition remain poorly resourced and addressed at present. In view of climate change, scaling up of all these actions is even more urgent.

Since most impacts of climate change are location-specific, international and national stakeholders should work to ensure that technical, financial, and capacity-building support reaches local communities [10]. These stakeholders should promote community-based and needs-driven approaches and encourage community participation in national planning processes.

Climate change adaptation and nutrition security

Direct nutrition interventions to build resilience to climate change impacts

Direct nutrition interventions can contribute to reducing vulnerability and building resilience to climate change consequences. The 2008 *Lancet* series on efficacious nutrition interventions and a 2009 World Bank study on the programmatic feasibility and cost-effectiveness of these interventions led to the identification of a package of highly cost-effective interventions, concentrating on the window of opportunity for children under 2 years of age but including some components with broader benefits, such as maternal undernutrition [1, 48].

These evidence-based, high-return nutrition investments include promotion of good nutrition, care, and hygiene practices, such as breastfeeding, complementary feeding for infants over 6 months of age, improved hygiene practices, including handwashing, and deworming programs; micronutrient supplementation for young children and their mothers (e.g., periodic vitamin A supplements and therapeutic zinc supplements for diarrhea management); provision of micronutrients through food fortification for all (e.g., salt iodization, iron fortification, etc.); and therapeutic feeding of malnourished children with special foods, including the prevention or treatment of moderate undernutrition and the treatment of severe undernutrition ("severe acute malnutrition") with ready-to-use therapeutic foods (RUTF) [1, 3].

Food assistance must be targeted directly to meet immediate food and nutritional requirements of vulnerable people, to increase their productive potential and adaptive capacity, and to protect them from climate-related disasters. Food assistance can be delivered, for example, by the provision of school meals, labor-based safety nets, or cash-based interventions, such as vouchers.

Sustainable, climate-resilient, and nutrition-sensitive agricultural development

Agriculture is fundamental to reducing global hunger and, along with health- and care-based approaches, is integral to improving nutrition outcomes worldwide [15]. Climate change instills greater urgency to find more sustainable, resilient, and efficient ways of producing, trading, distributing, and consuming diversified agricultural food products. Producing more food does not necessarily lead to better access to a healthy and balanced diet or to an improved nutritional status of those who need it most [49]. In Kenya and the Philippines, for example, the adoption of cash crops

expanded the food supply and doubled the household incomes of small farmers, but studies showed that children's energy intake increased by only 4% to 7% and that child undernutrition was little changed, because households tended to spend extra income on smaller quantities of more expensive, higher-quality foods and other basic needs [50].

Clearly, what seems to be lacking is a greater emphasis on the nutritional quality and dietary diversity of agricultural food production for local consumption in the developing country context. Climate-resilient agriculture should be nutrition-sensitive and health-promoting, and contribute to improving dietary diversity and nutrition by supporting the following measures, among others [15]: agricultural and farming extension services promoting better crop and food production diversity (including aquaculture) and biodiversity for improved nutrition; integrated agroforestry systems, in particular in areas with traditional agroforestry knowledge, that reduce deforestation and promote the sustainable exploitation of nutrient-rich non-wood forest products (which are also available to buffer in times of staple dietary shortages and failed harvests); integrated farming systems exploiting the synergies of horticulture, aquaculture, and small livestock rearing to reduce waste and expenses on agricultural inputs and increase food production diversity; better utilization of information on variability of weather and climate to manage climate-related risks for agriculture, forestry, and fishery; and enhancing the effectiveness of food and nutrition insecurity surveillance and early warning systems and their linkages to early response mechanisms.

In addition, education, communication for development, and social marketing strategies that strengthen local food systems and promote cultivation and consumption of local micronutrient-rich foods; research and development programs for the breeding of selected crops and livestock with enhanced nutritional quality; and improved postharvest management (food storage, transformation, handling, and processing) to reduce losses in quantity and nutrient content also contribute to nutrition security [15].

Agricultural policies must go beyond staples and increase the availability and affordability of a diverse range of nutritious foods (vegetables, fruits, legumes, animal and dairy products, small fish, underutilized nutrient-rich indigenous foods, etc.). Agricultural policies should be pro-poor by enhancing and sustaining people's ability to procure and use the amount and variety of food required to be active and healthy. Policies must also be gender-sensitive: the majority of small-scale farmers are women who are balancing their child-care responsibilities and farming every day. Particular attention should be given to strategies to reduce women's workload, taking into account the repercussions for the nutrition and care of children

[51]. Agricultural investment in sustainable, climate-resilient, gender-sensitive, and nutrition-sensitive development can contribute to reducing undernutrition among children under 5 years of age. The International Assessment of Agricultural Knowledge, Science and Technology for Development report (IAASTD) recommended reversing top-down transfers of technology and replacing them with bottom-up, participatory, farmer-oriented innovations [52].

Access to maternal and child healthcare, safe water and sanitation systems, and adequate, safe food

There is a need for additional investment and planning to address the new challenges posed by climate change to health-related issues [13]. Maternal and child health-care needs to be implemented successfully and to provide near-universal health coverage. Other important actions for minimizing health impacts from climate change include strengthening of public health systems and basic clinical care systems, including the availability of essential drugs; enhancing local capacities to address public health emergencies; strengthening surveillance systems of infectious disease; improving the use of early warning systems by the health sector; addressing known environmental risk factors and water-related diseases; integrating nutrition and hygiene education in interventions for the treatment of severe malnutrition, diarrheal illness, and other common childhood illnesses; and strengthening surveillance and control of food hazards and food-borne disease by food control and health authorities [13, 39, 53]. Greater emphasis needs to be placed on protecting the health of particularly vulnerable groups such as young children and pregnant and lactating women. The critical role of the nutritional status of adolescent girls and women prior to conception and during inter-pregnancy intervals needs to be specifically addressed and has rarely been mentioned. Rural communities and urban areas with high levels of maternal and child undernutrition, as well as communities with high infectious disease burdens from malaria, tuberculosis, and HIV, deserve specific attention.

Social protection schemes that have proven effective in addressing undernutrition and building resilience

Drought and other climate-related shocks frequently force poor families to resort to negative coping strategies, such as reduction of the quality, safety, and quantity of their meals, reduction of expenditures on health and education, sale of productive assets, etc. [23]. These coping strategies generally increase the risk of undernutrition [23] in the short or medium term, and women and children are the first to be affected. Food security and nutrition-related social protection mechanisms, including safety nets, can help vulnerable

households become less exposed, less sensitive, and more adaptive to a range of shocks [54]. They can be powerful instruments to link risk reduction and immediate protection measures with efforts to build long-term resilience among the most vulnerable groups [55], more specifically young children and their mothers. Given the critical role that women play in the nutrition of children, transfers should be delivered through gender-sensitive mechanisms.

Short-term emergency or seasonal safety nets can avoid irreversible losses in human capital, reduce the incidence of negative coping mechanisms, and protect the family's access to sufficient, nutritious, and safe food. Food- and cash-for-work programs prevent poor farmers from selling off their few productive assets during crises, thereby protecting development gains. Social cash transfers, generally delivered by governments on a permanent basis, can help poor families to reduce their vulnerability and may also directly influence nutritional status. Conditional cash transfer programs in Colombia, Mexico, and Nicaragua decreased stunting rates by 7, 10, and 5.5 percentage points, respectively [56]. Labor-based productive safety nets and pro-poor insurance schemes can allow poor farmers to protect their productive assets and to gain access to investment opportunities that they would otherwise miss.

School-based approaches (school feeding programs, school gardens, nutrition education, etc.) can support child nutrition through improved diets and food and nutrition education and provide a platform for addressing child health. When children are reached during the critical period between conception and 2 years of age, the irreversible and intergenerational effects of under-nutrition can be prevented.

In view of recurrent disasters, there is also a growing demand for more predictable, flexible, and long-term safety nets that take into account climate risks [57]. Innovative examples of climate risk management have already been developed and could be scaled up and replicated. One example is the Livelihoods, Early Assessment and Protection (LEAP) project, in which the World Food Programme, supported by the World Bank, has assisted the Government of Ethiopia in the development of a comprehensive national weather risk management framework. LEAP links Ethiopia's Productive Safety Net Program to a contingency fund. Based on a weather index, a tailored LEAP software program estimates the costs of scaling up the Productive Safety Net Program, allowing for a timely response in case of droughts or floods [58].

Empowerment and social participation within climate-resilient and nutrition-sensitive community-based development

Empowerment and social participation of women

and other vulnerable groups is necessary throughout the decision-making, planning, and implementing processes. Investments for community food and nutrition security [23] should target strengthened legal rights and equal access to resources, including land, for both women and men; support responsive institutions grounded in the local context; expand and improve education and livelihood options; support gender dynamics, gender equality, and girls' education; enhance local capacities by building on local, indigenous, and traditional knowledge with institutions at all levels; and create a restored, diversified natural resource base and ensure that populations have the capacities and means for sustainable management of their natural resources.

In addition to a rural focus, attention has to be given to urban and periurban areas. The food supply in urban and periurban areas can be put at risk by climate change hazards (for instance, as a result of interruption of supply channels). These perturbations can have an important impact on the growing urban and periurban populations, in particular the poorest and most vulnerable living in precarious conditions in slums, with no access to social protection or safety nets. Young children, adolescent girls, and pregnant and nursing women in rural, urban, and periurban areas should receive special attention.

Nutrition-sensitive disaster risk reduction and management

With increasing risks of climate-related disasters, there is a need to better protect those who are already food and nutrition insecure by developing nutrition-sensitive disaster risk reduction strategies and risk management practices. There is a reservoir of important indigenous and traditional knowledge in hazard-prone communities. Policy makers and practitioners should capitalize upon this existing knowledge and promote positive local risk management and coping strategies. In line with the Hyogo Framework of Action (2005) [59], key areas would be participatory, nutrition-focused risk assessments and risk reduction plans; effective nutrition surveillance and early warning systems, coupled with early response mechanisms; disaster preparedness for effective response to adverse hazard events and capacity to address nutrition emergencies; contingency planning and stockpiling of emergency nutrition supplies; and building resilience of food- and nutrition-insecure communities to disasters. The potential of innovative microinsurance schemes targeting food- and nutrition-insecure households should be further explored. Quality climate risk and early warning information should be accessible to communities, with a special focus on women, to decision makers, and to humanitarian stakeholders at all levels. These stakeholders should improve their ability to prepare for and

provide early responses to disasters and to food and nutrition crises. They should also be ready to cope with increased demand for support, in light of the increasing frequency and severity of climate-related hazards.

Climate change mitigation: Nutrition-sensitive climate change mitigation measures

Climate change mitigation measures need to be put in place urgently in all the sectors to reduce the diverse impacts of climate change, including those on food and nutrition security. The agriculture sector substantially contributes to greenhouse gas emissions worldwide and therefore offers a significant potential for mitigation [46, 60]. One of the most potent greenhouse gases is methane, which is emitted in the digestive processes and manure of ruminant livestock. The mitigation potential of reduced methane emissions from the agricultural sector is estimated at between 17% and 40% [61]. Agriculture, in particular livestock production, is also a driver in deforestation, the climate impacts of which are thus often considered in the agricultural context [62].

Climate change mitigation in the agriculture sector calls for pro-poor and sustainable strategies that avoid compromising food and nutrition security [11, 28, 63]. At present, the low- and middle-income countries face the challenge of investing more in agriculture and ensuring food and nutrition security for their populations, strengthening the resilience of their food production systems to climate change, while also reducing emissions from agriculture. Specific agricultural development pathways with low net greenhouse emissions can help achieve this triple objective in low- and middle-income countries, in particular agroecological food production systems, low external input agricultural systems, and integrated agroforestry and silvo-pastoral systems [11, 46, 64]. The Climate Change, Agriculture and Food Security research program (CCAFS) of the Consultative Group for International Agricultural Research (CGIAR) and the Climate Smart Agriculture initiative proposed by the Food and Agriculture Organization and the World Bank promote these triple-win development pathways [63, 65–67]. The CCAFS also promotes the development of pro-poor climate change mitigation measures by enhancing the effective capacity of the poor to benefit from carbon financing [63].

Agriculture-related strategies and non-agricultural mitigation measures that bring co-benefits in sustainable food production, enhanced food production per unit of energy, land, and water resources consumed, as well as enhanced access to nutritional foods and to health in low- and middle-income countries should be further tested, encouraged, and scaled up [11, 46, 62, 68–70]. Non-agricultural mitigation measures

include, for example, diffusion of the low-emission stove technology for burning local biomass fuels, which can reduce the risk of respiratory conditions in young children. Strategies to reduce the production and consumption of foods of animal origin would help to prevent greenhouse gas emissions while benefiting the health of adults in countries consuming large amounts of products of animal origin [62]. Mitigation strategies that aim to reduce the carbon footprint of the whole food sector through sustainable food production, sustainable food consumption, and food waste reduction should be explored and encouraged [62, 69, 70].

Recognition that climate change mitigation strategies, nutrition, and health are intertwined should lead to a more systematic assessment of the health and nutrition impacts of mitigation strategies and more integrated solutions and policies. Such approaches can be more cost-effective, more equitable, and socially attractive. They can generate greater overall benefits for food and nutrition security, health, and climate protection.

Implications of changing diets

In very-low-income settings, better access to animal products may be essential to improve nutrition among groups lacking access to diverse food sources. Livestock production is also a critical component of income and food security among many rural populations, including the rural poor. But at the same time, many high- and middle-income countries are facing an epidemic of obesity that is also fueled, in part, by increased consumption of animal products [62].

Global trends in meat consumption and livestock production have an impact on the environment and climate change but can also have profound long-term impacts on the production, availability, and pricing of certain basic food commodities. As previously noted, some one-third of agricultural cropland is devoted to the production of feed for livestock [45, 46]. As a result of this and other factors, the production of certain kinds of animal protein, particularly beef, is more greenhouse gas-intensive per unit than cultivation of alternative plant-based protein sources [71] and thus contributes more to climate change. In a world of finite land, water, and energy resources, the expected trends of continued rapid growth in global livestock production may constrain investments of land, water, and resources into alternative sources of nutritionally rich and diverse food crops. Imbalances in agricultural production patterns are inevitably going to be reflected in imbalances on the dinner plate. These in turn may perpetuate trends of obesity in middle- and high-income countries but also constrain the ability of nutritionally vulnerable groups to both cultivate and purchase nutritionally rich, diverse diets more

affordably [72, 73].

Patterns of human consumption over time have shown a steady shift in diet preferences as incomes increase and socioeconomic shifts, such as urbanization, occur. In general, the per capita level of cereal consumption declines with increasing income, whereas that of meat increases [74]. Consumption by high-income countries is growing far beyond the world average, while the growth in dynamic economies such as China and Brazil accounts for much of what is observed in East Asia and the Latin America region. The options for mitigation are not as straightforward, however, when it comes to changing human consumption patterns as for technological efficiency in conversion or energy generation. The instruments that policy makers have to influence household-level consumption choices are not nearly as direct as those which might influence industries or the decisions of political entities that control their regulation. The decrease in feed grain consumption that would result from a shift in preferences that lowered growth in per capita meat consumption in high-income countries could be as large as 5% when compared with the baseline case, and could be as high as a 14% decrease in feed grain consumption, if the fast-growing economies (and consumer cultures) of China and Brazil were also to exhibit a shift from the expected growth in meat consumption [74]. This would have implications for food market prices, price-driven nutrition outcomes, and even land use changes, which have direct impacts on greenhouse gas emissions from agriculture, as reflected in a recently released comprehensive study for the European Union region [75].

Sustainable food production and consumption through the promotion of sustainable diets have been proposed as strategies to direct consumers' choices toward more sustainable and healthy food patterns [76]. Sustainable diets have also been recommended to address malnutrition, ecosystem degradation, and biodiversity loss caused, at least in part, by changes in dietary patterns [76]. This requires a major interdisciplinary effort. The notion of sustainable diets contributes as well to the promotion of food biodiversity, including traditional foods of indigenous peoples.

Financing nutrition, a sound investment for the future

There is a need for additional investment to address the new challenges posed by climate change to food and nutrition security in low- and middle-income countries. Existing and emerging Climate Funds should be mobilized to support nutrition-focused adaptation actions and target as a priority women and children in communities most at risk for undernutrition. National adaptation plans should ensure adequate budgetary allocations and incorporate the appropriate actions to

address nutrition problems. Climate Funds and other private investments should also support climate change mitigation measures that bring nutrition co-benefits. Better nutrition strengthens communities and local economies and contributes to the achievement of other development and adaptation objectives.

Empirical evidence demonstrates that interventions aimed at reducing undernutrition have a greater and much more rapid impact on poverty than economic growth on its own: whereas a 1% decrease in the poverty rate achieves a 0.25% reduction in the malnutrition rate, a reduction of 1% in undernutrition eventually yields a 4% decrease in poverty [77]. Therefore, nutritional interventions are essential to speed up the reduction in poverty. Investment in child nutrition is core to achieving improvements in health and education outcomes and in economic growth and is a prerequisite for poverty reduction. These investments should be done at early stages of nutrition crises, first in order to prevent long-term adverse effects on the lives of the malnourished, but also because early responses are more cost-effective, as illustrated by the recent crisis in Niger. This food crisis was anticipated from 2004; the international community was sensitized in November 2004 and again in May 2005, with little assistance forthcoming. This allowed Niger to slip into crisis, so that by July funding needs had risen exponentially. The United Nations calculated that "it would have cost \$1 a day to prevent malnutrition among children [in Niger] if the world had responded immediately. Now it will cost \$80 to save a malnourished child's life" [78].

Strategic capacities for policy development, institutional accountability, and good governance

A number of policy, institutional, and governance issues have considerable influence on food and nutrition security. Reaching and sustaining food and nutrition security in a changing climate requires a multi-sectoral approach involving nutrition, agriculture, health, and social protection. There are also important links to education, water supply, and sanitation, as well as to cross-cutting issues like gender equality, governance, and state fragility.

The cross-sectoral nature of nutrition, the impacts and threats of climate change, and the potential negative implications of climate change mitigation actions for nutrition call for increased policy coherence and institutional and cross-sectoral collaboration at the local, national, and international levels. Mechanisms that ensure this policy coherence between food and nutrition security, development, adaptation, and mitigation objectives should be explored and implemented at all levels. Effective cross-sectoral planning and solutions should be facilitated by joint efforts and

partnerships among communities and local stakeholders, governmental and public agencies, United Nations agencies, civil society, the private sector, and academia. It is necessary to strengthen the capacities of the various stakeholders involved in direct nutrition interventions, food production and access, and social protection systems and also to improve their ability to prepare for and respond to disasters.

Many low- and middle-income countries lack the adequate institutional framework and human resources to implement nutrition-based agendas [79]. Special efforts are needed to raise awareness of nutrition and climate change among decision makers and policy makers, to strengthen national capacities, and to bridge the gaps between sectoral institutions. At the international level, there is a need for nutrition policy coherence and cooperation to eradicate malnutrition in all its forms [11, 28], including both undernutrition and overnutrition. Stakeholders involved in the UNFCCC climate change discussions should draw on support from related international forums and initiatives, such as the (UNSCN), the SUN movement, the Committee on World Food Security, the UN High Level Task Force on Global Food Security, the REACH partnership, the International Health Partnership, and the Zero Hunger initiative. There is still a gap between affected communities and the national and multilateral debates. It will be necessary to link the local-level voices, experiences, and expertise to the national and international climate change agendas for adaptation and mitigation to succeed.

Conclusions and recommendations

Climate change directly affects food and nutrition security, undermining current efforts to address undernutrition, one of the world's most serious but least addressed socioeconomic and health problems.

Within broad efforts on climate change mitigation and adaptation, a combination of direct nutrition interventions, nutrition-sensitive development measures, nutrition-smart investments, increased policy coherence, and institutional and cross-sectoral collaboration can address the threats to food and nutrition security in a climate change environment. Nutrition and health scientists need to be engaged in the assessment by the IPCC and in key climate change adaptation and mitigation initiatives. Nutrition-sensitive adaptation and mitigation measures should be integrated with development strategies and programs. Changes in policies, institutions, and governance will be needed to facilitate this intersectoral approach [11, 28] A rights-based approach engages the rural, periurban, and urban stakeholders who are most vulnerable and affected by climate impacts as active participants in this process.

Comprehensive long-term cooperative actions in

the frame of the UNFCCC are needed to formulate clear responses in order to protect nutrition from the effects of climate change. The UNFCCC negotiators have the opportunity and the responsibility to consider and address nutrition in the strategies defined in the frame of the AWG-LCA and the Nairobi work program undertaken under the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA). The presence of a global agreement on regulation of greenhouse gas emissions and climate change mitigation would provide a more favorable environment for country-level policy makers to enact programs aimed at raising awareness of the human and environmental health impacts of production and consumption patterns, which would be politically difficult otherwise.

Particular recommendations to address nutrition in the climate change agenda include the following:

Include nutrition within the shared vision

The shared vision section of the AWG-LCA should recognize that climate change directly affects the food and nutrition security of millions of people, and indicate that joint comprehensive short- and long-term approaches are needed to preserve and improve nutrition security while addressing climate change. Strategies to respond to climate change through adaptation, mitigation, finance, technology, and capacity-building should properly take into account the impact of climate change on nutrition security.

Make climate change adaptation nutrition-sensitive

Nutrition should be integrated in the enhanced action on adaptation with increased attention on those most vulnerable to undernutrition, such as mothers and young children. Nutrition security should be explicitly addressed in climate-resilient development, national adaptation, and disaster risk reduction plans in low- and middle-income countries. A revitalized twin-track approach to ensure food and nutrition security could reduce vulnerability, build resilience, and secure nutrition under a changing climate. Track 1 consists of the up-scaling of nutrition-specific interventions, food assistance, and safety nets. Track 2 consists of a multi-sectoral nutrition-sensitive approach to sustainable and climate-resilient agriculture, health, and social protection schemes and safety nets, risk reduction and risk management plans, and climate-resilient, community-based development.

Include nutrition considerations in all climate change mitigation efforts

The mitigation section of the AWG-LCA should mention that mitigation strategies with co-benefits for nutrition, health, and the environment, such

as sustainable food production, sustainable diets, sustainable food consumption, and waste reduction, should be explored and encouraged. Nutrition-sensitive mitigation strategies that bring co-benefits in enhanced production of and access to food and enhanced health should be further explored, tested, and scaled up. Agricultural mitigation measures need to be explored in the context of climate change to identify those strategies that can be most effective for food security, nutrition, and health in the short and long term. Investments in research are essential to obtain further evidence to determine which mitigation actions have negative effect on nutrition security and identify alternative nutrition-sensitive solutions. A more balanced approach to meat production and dietary meat consumption is also essential to effective agricultural mitigation and better nutritional balance in both high- and low-income populations.

Ensure that finance, technological development, and capacity-building on climate change are nutrition-sensitive

The finance section of the AWG-LCA should stress that support for adaptation and mitigation should protect and improve nutrition. Climate Funds and private investments that will finance climate change adaptation and mitigation in low- and middle-income countries should be nutrition-aware, with national adaptation plans ensuring adequate budgetary allocations and actions to address nutrition problems. Climate Funds should finance mitigation strategies that bring co-benefits and enhance adaptive capacity for food and nutrition security and nutrition-sensitive technological innovation. It is necessary to strengthen the capacities of national governments to protect and enhance nutrition security under a changing climate, and to integrate nutrition into climate-resilient development and adaptation plans.

Achieve policy coherence on climate change and nutrition

Mechanisms that ensure policy coherence between food and nutrition security, development, adaptation,

and mitigation objectives should be explored and implemented at all levels. It is necessary to improve collaboration and communication among stakeholders to develop coherent and coordinated nutrition-aware institutional and policy frameworks at the local, national, and international levels, to address the impacts of climate change on nutrition. Stakeholders involved in the climate change discussions should draw on support from the UNSCN and other related international institutions and initiatives, such as the Committee on World Food Security.

The current climate change negotiation process at the UNFCCC, the adaptation efforts, and the post-2015 framework offer a unique opportunity to take on board key actions needed to protect nutrition in a comprehensive way. Further multi-sectoral efforts, leadership, and political will are required to integrate nutrition-sensitive actions into sustainable development efforts in view of the post-2015 development agenda. Placing human rights at the center of strategies to adapt to and mitigate the impacts of climate change and international solidarity is essential to advance the agenda toward sustainable development and to create a climate for nutrition security.

Authors' contributions

M. C. Tirado and P. Crahay provided overall leadership on the conceptual development of the paper and prepared the first and subsequent drafts with inputs from other authors.

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