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The effect of climate change across food systems: Implications for nutrition outcomes

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ABSTRACT

A better understanding of the pathways linking climate change and nutrition is critical for developing effective interventions to ensure the world's population has access to sufficient, safe, and nutritious food. The paper uses a food systems approach to analyze the bidirectional relationships between climate change and food and nutrition along the entire food supply chain. It identifies adaptation and mitigation interventions for each step of the food supply chain to move toward a more climate-smart, nutrition-sensitive food system. There are many entry points for "double duty" actions that address climate adaptation and nutrition but they need to be implemented and scaled by governments.

1. Introduction

Humanity is already witnessing the repercussions of climate change. Without mitigation and adaptation, these impacts will intensify as time progresses. Climate change presents unique challenges to the world's ability to meet food security and nutrition needs, which will increase into the future (Lobell et al., 2008; United Nations System Standing Committee on Nutrition Secretariat, 2010). Food systems are highly sensitive to climate, as they are both "victims" and instigators of the effects of climate variability and longer-term climate change.

The future effects of climate change will be most evident among populations in the Global South, especially sub-Saharan Africa and South and Southeast Asia (Intergovernmental Panel on Climate Change, 2014). Many people in these regions are rural and experience poverty, and their livelihoods, as well as many of the systems they engage with, including health, education, and food systems, can be significantly affected by climate change. Countries and communities that do not have adaptation strategies in place will likely see a reversal of previous gains in reducing food insecurity and undernutrition. In 2017, for the first time in over a decade, the number of those who are undernourished has increased due to climate change as well as conflict (FAO. IFAD. UNICEF. WFP. and WHO, 2017).

Climate change, agriculture, and nutrition are interconnected. Climate change and variability affects temperature and precipitation, as well as frequency and severity of extreme weather events. Increases in temperature, heat waves, and droughts will impact agriculture, with the largest effects being decreased crop yields and livestock productivity, as well as declines in fisheries and agroforestry in areas already vulnerable to food insecurity (FAO. IFAD. UNICEF. WFP. and WHO, 2017). There is strong evidence that climate change will affect food quality (diversity, nutrient density, and safety) and food prices (GLOPAN (Global Panel on Agriculture and Food Systems for Nutrition), 2015; Vermeulen et al., 2012).

The effects of climate change on agriculture will, in turn, have significant implications for food security, and thus human diets and nutrition. As climate change affects the ability to move food from production to markets, access to diverse, high-quality diets may become more limited. Reduced access to sufficient nutrient-dense foods will subsequently lead to impaired nutritional status and diminished resiliency, particularly in low-income communities (United Nations System Standing Committee on Nutrition Secretariat, 2010). Even in the "business-as-usual" models, nutrition and health outcomes are likely to worsen (FAO, 2016a; Springmann et al., 2016a; Whitmee et al., 2015).

The purpose of this paper is to examine the relationships between climate change, diets, and nutrition through a food system lens. The paper begins with the impacts of climate change on nutrition. It discusses the interrelated nature of climate change, food systems, and diets: climate variability disrupts food systems and diets, yet food systems and diets also have repercussions for climate change. Thereafter, the paper describes promising "climate-smart, nutrition-sensitive" mitigation and adaptation actions to improve food systems, diets, and

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nutrition.

A recent paper by Myers et al. (2017) nicely outlines these potential relationships (Myers et al., 2017), while this paper provides additional insight into the impacts of climate change on value chains within the food system relevant to the rural poor. The paper focuses on undernutrition in low- and middle-income countries (LMIC), as undernutrition is currently more prevalent among our target population and LMICs account for nearly all the global burden of stunting (Development Initiatives, 2017). Though the alarming rise of overweight, obesity and non-communicable diseases in this population warrants attention, the relationship with climate change has been explored elsewhere and will not be the focus of this paper (An et al., 2018). The primary emphasis is on the rural poor, a group especially vulnerable to the adverse effects of climate change on nutrition. Other populations, including the urban poor and rural populations working outside of agriculture, also face significant vulnerabilities from climate change but are not addressed in depth here. The paper also examines inequities related to the global food system's influence on climate change.

2. Impacts of climate change on nutrition outcomes

The implications of climate change extend across all determinants of malnutrition. These determinants range from underlying factors, such as socioeconomic status and environmental conditions, to more direct determinants, such as food and nutrient intake, and disease (Black et al., 2013). The effects of climate change on nutritional status vary based on wealth and livelihood, but overall, the burden of undernutrition is projected to worsen relative to a no-climate-change scenario (Grace et al., 2012).

Climate change can exacerbate undernutrition through three main pathways: household food security (access to safe, affordable, and sufficient food), child feeding and care practices, and environmental health and access to health services (Met Office and WFP, 2012). Climate change affects what food is available and at what price, impacting overall calorie consumption as well as consumption of healthful foods (Nemecek et al., 2016; Springmann et al., 2016b; Whitmee et al., 2015). This in turn can have an impact on stunting and micronutrient deficiencies. Moreover, many responses to climate challenges also have implications for women's labor allocation, which in turn influences women's time available for child feeding and care practices (Bryan et al., 2017). Finally, health status impacts how nutrients in consumed foods are absorbed and used by the body. Decreased water quality and availability in some areas could result in increased sanitation problems and water-borne diseases such as diarrheal disease (Met Office and WFP, 2012), while the transmission of vector-borne diseases is projected to increase with climate change (Akresh et al., 2011). Coupled with a potential disruption in access to health facilities and health care service delivery by climate shocks, these changes in the environment have the potential to affect nutrient utilization and increase undernutrition (Met Office and WFP, 2012).

Undernutrition carries profound, long-lasting consequences, especially for children under the age of five. Stunting affects approximately 155 million children under five and has long-term implications for individuals, households, and communities (UNICEF / WHO / World Bank Group, 2017; Victora et al., 2008). Stunting in the first two years of life can lead to lowered cognitive functioning and reduced adult income (Briend et al., 2015; Victora et al., 2008). Approximately ten percent, or 50 million, of the world's children under five years are wasted (Black et al., 2013; UNICEF / WHO / World Bank Group, 2017). Child wasting is associated with reduced lean mass, increased risk of infection, and mortality (Briend et al., 2015). By some projections, medium-high climate change is expected to result in an additional 4.8 million undernourished children by 2050 (Table 1) (IFPRI, 2017). This is supported by evidence linking the dire effects of malnutrition with productivity and health at different scales, be they individual, household, community, national, or global levels (Victora et al., 2008).

Climate change and variability lead to seasonal effects that have important implications for nutrition and health. Changes in rainfall (level, pattern, or variability) can result in crop failures and flooding, which can affect nutritional status, particularly stunting outcomes (Akresh et al., 2011; Phalkey et al., 2015), potentially due to a loss in livelihood and decreased access to food. Increased temperatures have been shown to increase the risk of heat stress during pregnancy, as pregnant women are hypothesized to be more sensitive to warm temperatures (Grace et al., 2015). The additional physical and emotional stress caused by these temperatures affects the development of the neonate which influences birth weight outcomes (Grace et al., 2015). Studies show that the combination of increased temperatures, regional decreases in rainfall, and unstable food production will result in an increased risk of future low-birth-weight babies in sub-Saharan Africa (Grace et al., 2015). Drought has the potential to lead to food shortages as well as loss of income, resulting in slowed growth in children younger than two (Hoddinott and Kinsey, 2001). Flooding has short- and long-term effects on child growth through changes in food consumption and infectious disease burden (Danysh et al., 2014; del Ninno and Lundberg, 2005; Rodriguez-Llanes et al., 2011).

The effects of climate change also have the potential to worsen the intergenerational cycle of malnutrition. These intergenerational effects have a detrimental impact on child growth: short maternal stature, occurring as a result of poor nutrition in childhood, is associated with low birth weight and child stunting, which thus begins the malnutrition cycle anew (Martorell and Zongrone, 2012). Because climate change results in short-term shocks and long-term stressors, it will have an impact across the entire life cycle (Fanzo et al., 2017b; Thomson and Fanzo, 2015). Interventions are needed for infants and young children before the age of two, when rapid growth faltering typically occurs (Victora et al., 2010), as well as during later childhood, adolescence, and pregnancy (Prentice et al., 2013).

3. Impacts of climate change on food systems and diets

Food systems include all aspects of the food supply chain, from agricultural production through storage, processing and distribution, retail and marketing, and home food preparation and consumption (HLPE, 2017). Modeling indicates the impact of climate change on food systems will be widespread and variable, both geographically and temporally, as influenced by socioeconomic conditions (Vermeulen et al., 2012).

The *food supply chain* provides a useful framework for examining how climate change will impact our food system and evaluating where nutritional outcomes may be at risk. Each step in the chain can be evaluated for vulnerabilities, and interventions can be designed and “leveraged for change” to address food insecurity and malnutrition (Gelli et al., 2015; Hawkes and Ruel, 2012). Food supply chains determine what food is available, as well as the nutritional quality of those foods (Gelli et al., 2015; Maestre et al., 2017). The food environment, or the distribution of food stands, kiosks, stores, restaurants, or any other retailers where food can be obtained, as well as the cost of food and sociocultural factors around food, determine what food people have access to in terms of availability and price (HLPE, 2017). Additional factors, ranging from personal preference to convenience, further influence what foods people buy and consume (Sobal et al., 2014). The diversity of what people consume is critical for nutritional status and health. Dietary diversity, as measured through the number of food groups and the amount of nutritious vegetables, fruits, and animal source foods (ASF) consumed, is connected to adequate nutrition, especially micronutrient adequacy (Arimond et al., 2010; Ruel et al., 2013). Models estimate more than 500,000 additional deaths in 2050 due to climate–related changes in diets, including decreased food intake and decreased vegetable and fruit consumption, between the years 2010 and 2050, with large regional variations (Springmann et al.,