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Research Article

An overview of the influence of climate change on food security and human health

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Abstract

Climate change is increasing the frequency of climate-related disasters, creating greater risks of hunger and the breakdown of food systems. The sustainability of our planet is currently a major concern for the global community and has been a central theme for a number of major global initiatives in recent years. Climate change has prevalent, multi-faceted, and temporal impacts on food security. Higher temperatures, water scarcity, extreme events like droughts and floods and greater CO_2 concentrations in the atmosphere have already begun to impact staple crops around the world. The warming climate is already taking a toll on human health, causing widespread hunger and illness that will grow exponentially worse, and will pose a major threat to human well-being. In this article, an attempt has been made to discuss some critical issues relevant to the four dimensions of food security and to provide broader perspectives on climate change and its impacts on the food system, food security and human well-being.

"*Humanity is facing a rare challenge. But it is a common challenge. There are no sides in the fight for climate justice*" (Kofi Annan's message prior to the UN Climate Conference in Copenhagen 2009).

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Introduction

Science is now unequivocal as to the reality of climate change [1]. Human activities, in particular emissions of greenhouse gases like carbon dioxide, are recognized as its principal cause, explained through worldwide devastation and suffering. 2019 has registered as one of the hottest years of a series of five-year periods that ranks as the warmest span in recorded history. In 2019, global losses of $150 billion were incurred due to hurricanes, wildfires and floods which are continuing to this day. This decade-long rise in catastrophes cost businesses and the economy enormous losses with direct links to climate change [2]. As disasters have increased in frequency and severity over the past 30 years, there are impacts on health, water supply, and other shocks not taken into account. The human impact of climate change is happening right now — it requires urgent attention.

The links between food security and climate change are complex because food security involves food and its production, trade and nutrition as well as how people and nations maintain access to food over time in the face of multiple stresses [3]. Climate change threatens our ability to ensure global food security, eradicate poverty and achieve sustainable development [4].

The impact of climate change disproportionately affects the poor and vulnerable [5,6]. Developed nations are also seriously affected and increasingly so. The human impact of recent heatwaves, floods, storms and forest fires in rich countries has been alarming [7]. Australia is perhaps the developed nation most vulnerable to the direct impacts of climate change and also to the indirect impact from neighboring countries that are stressed by climate change [8].

Combatting climate change must go hand in hand with alleviating poverty [9]. The adverse effects of climate change are greater among poor people in developing countries who are highly dependent on climate-sensitive natural resources yet have the least adaptive capacity to cope with climate impacts [10]. The international community agreed at the beginning of the new millennium to eradicate extreme hunger and poverty by 2015. Yet, today, climate change is already responsible for forcing some fifty million additional people to go hungry and driving over ten million additional people into extreme poverty. Between one-fifth and one-third of Official Development Assistance is in climate-sensitive sectors and thereby highly exposed to climate risks.

Climate change is projected to negatively impact the four

pillars of food security – availability, access, utilization, and stability – and their interactions [11]. Meeting global food security needs remains a challenge, as food and protein demand increases at a rate even faster than the population growth [12]. Climate variability has taught mankind to adjust to its fluctuations spanning various timescales, from daily to decadal. But presently time is beset with very rapid changes in global mean temperatures, as the atmospheric concentration of greenhouse gases (GHG) increases. The most at risk will be the poor from developing countries, who contribute the least to emissions of GHG, and will have to learn to adjust with little financial or technical resources [13].

Amongst the four components, food availability is most intimately associated with climate and its changes, from crops to animal products, marine and aquaculture products, and wood and non-wood products from forests. Even when production is sufficient, if a system of food allocation, whether it is through the market or not, is negatively affected, food access is impaired and food security is compromised [4]. Urbanization is rapidly taking place in many countries of the world, creating a category of urban poor who do not themselves farm and are very vulnerable to climate change [14]. The changes in climate variability have a direct implication on food-production system stability.

As the climatic system changes, the intensity and frequency of extreme events such as drought and flood would disrupt the stability, of both local and global food markets. This is expected to increase the occurrence and magnitude of food emergencies, as political conflicts and migration increase the pressure of sharing limited resources [13].

The objective here is to chalk out the relationship between the food system, climate change, and human well-being, drawn from evidence documented in research articles and official reports of the IPCC, FAO, and UN, which gives evidence of the prominence food has gained in the recent past. It has been attempted to provide an in-depth understanding of and to discuss some critical issues relevant to four dimensions of food security and to provide broader perspectives on climate change and its impacts on the food system, food security, and availability of foods, which ranges from production to processing, storage, distribution and exchange.

Methods

The study builds on secondary information found in relevant and recent food security literature under a changing climate. The objective of this paper is to draw a relationship between food, environment and climate change and to focus on how climate uncertainty is impacting food security and human health. The criteria applied to choose studies that fit the study's parameters are shown below:

1. A focus on climate change and its impact on food security
2. The risk of climate change on food availability and human wellbeing
3. The food systems approach to food security.

This study mostly used Google Scholar to obtain relevant research outputs and included only pertinent articles written in English. The search terms used included "food systems and sustainability goals", "food security and climate change," "food security and human health", "food security and food supplies", "food insecurity and developing countries", "smallholder farmers and climate change" some of the terms were used interchangeably.

Of the 265 available studies in Table 1 120 were selected after screening the titles and abstracts in the English language and finally after a full-text review, 56 published articles were found relevant matching the selection criteria and usable for this brief review article.

Table 1: Quantification of data .

Inclusion and Exclusion Criteria	Number of Results
Availability	265
Suitability of results to the research question	120
Inclusion of peer-reviewed results	56

The evolution of the concept and definitions of food security

Poverty, inequality, and food insecurity are among the key challenges of our time, yet improving food availability is not enough to eliminate poverty and hunger [12] as envisaged under SDG 2 of sustainable development goals. The notion of food security evolved close to half a century ago and has been gradually enlarged. Initially, it focused mainly on the availability of food and on food production, then it was expanded to include explicitly the accessibility to food (physical, economic, and socio-cultural), its utilization, and lastly to encompass the stability of these dimensions. The task of defining the concept of food security evolved from the World Food Summit in 1996, which says "food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [3,15].

Addressing food security is a complex issue that requires organizations and offices to work across sectors. The human population has always been in the grip of hunger and malnutrition. The origin of modern food security has been reported less than a century ago since the early 1930s. The first initiative to focus on the importance of food for health was taken by Yugoslavia, which proposed to the health division of the League of Nations, to disseminate information about food position to the representative countries of the world. This report introduced the world food problem on the international political platform for the first time [16].

Aside from the origin of modern food security, this first period had precedence of some events which were all related to factors directly or indirectly influencing world food security [17]. The increasing inequality in food security between developed and developing countries in the aftermath of the two world wars, where population increase outpaced increases in production many people were undernourished and malnourished or both. It was under such pressing conditions that the Food and Agricultural Organization of the United Nations (FAO) was founded [18].

FAO [19], recognizes four key components of food supplies to define food security: availability, stability, access and utilization. The first dimension relates to the *availability* of sufficient food that is to the overall ability of the agricultural system to meet food demand. It depends on the agroecological requirements of the crop and pasture production, as well as the socioeconomic and cultural factors that influence a farmer's performance in response to market demand. The second dimension, *stability*, relates to individuals who are at high risk of temporarily or permanently losing their access to the resources needed to consume adequate food, risking a deterioration in nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on an individual's food security status. The third dimension, *access*, covers access by individuals to adequate resources (entitlements) to acquire appropriate foods for a nutritious diet. Entitlements are defined as the set of all those commodity bundles over which a person can establish command given the legal, political, economic, and social arrangements of the community of which he or she is a member. Thus, a key element is the purchasing power of consumers and the evolution of real incomes and food prices. However, these resources need not be exclusively monetary but may also include traditional rights, e.g., to a share of common resources. Finally, *utilization* encompasses all food safety and quality aspects of nutrition; its subdimensions are therefore related to health, including the sanitary conditions across the entire food chain. It is not enough that someone is getting what appears to be an adequate quantity of food if that person is unable to make use of the food because he or she is always falling sick [20].

Berry, et al. [21], reiterate that the concept of food security is the outcome of an intermittent global food crisis. The economic crisis of the 1970s bolstered by the currency and energy markets led to extreme instability of agricultural commodity prices. The repeated occurrence of famine, hunger and food crises necessitated a new approach to food security, which recognized the critical needs and behavior of potentially vulnerable and affected people. Thereafter food security was redefined as the international community met in 1974 at the World Food Conference and defined food security as '[the] availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices'. The emphasis in this definition has been put on increased production since macronutrient hunger in 1970 was thought to affect 25% of the global population (and more recent FAO revisions imply that up to 30% was then hungry).

Jarosz [22], observes a shift in the definition of food security in publications of the UN Food and Agricultural Organizations (FAO) and the World Bank. Initially, the focus has been on the attainment of food security at the international and national levels to a micro-level focus on households and gendered individuals. This shifting paradigm from the international level of world regions and nations to poor households and individuals reveals, the boundaries between the haves and have-nots, the powerful and the vulnerable are deepened.

More than two hundred different definitions of food security exist to date [16,21,23] access to food has gained prominence and is central to most recent definitions, which has helped elevate its understanding otherwise focused only on food production. Generally, food insecurity emanates from an inability to access food, some parts of the world, especially sub-Saharan Africa, still face chronic hunger due to low food production. This can be due to degraded and infertile soil and also a lack of sufficient land or political instability. Many such areas are also anticipated to be most severely affected by global climate change [23]. The challenge under the current scenario for the research community lies in relocating focus on a more integrated approach by thinking more broadly, linking access to food to climate change.

Climate change, the food system and food security

The concern for ensuring food security under climate change led to developing a relationship between food, and the environment and climate change, which gained prominence since the Rio Declaration in 1992, where food production is Chapter 14 of Agenda 21, to the Paris Agreement of 2015, includes the need for food security. This growing prominence of food is reflected in recent IPCC reports, including its Fifth Assessment Report [24] and the Special Report on global warming of 1.5 °C (SR15) [11,25].

Food security is projected to be impacted negatively due to rapid population growth in developing countries [26,27], coupled with global climate change, and the recent economic downturn [28]. There are expected to be 9.8 billion people by 2050 [29,30], and climate uncertainties are already showing signs of crop production decline [31]. The capacity of the earth's resources to meet the growing food demand already stands challenged. Global agriculture is faced with the pressure of feeding the increasing number of mouths, constrained by climate change, land availability and degradation, loss of biodiversity and food insecurity [32].

The food system (Figure 1) encompasses all the activities and actors in the production, transport, manufacturing, retailing, consumption and waste of food and their impacts on

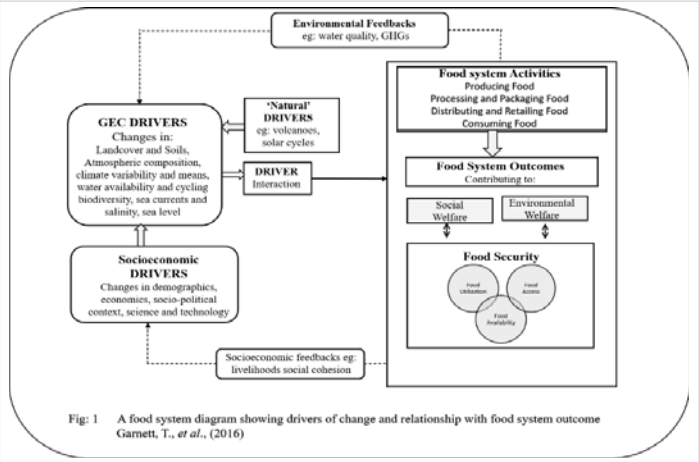

Figure 1: A Comprehensive Illustration of the Global Food System.

nutrition, health and well-being, and the environment [11,23]. The food system is supported by the biosphere along with all other manifestations of human activities. As a consequence of changes in the average weather conditions, it is projected that wet regions will become wetter and dry regions dryer. In response to this variability, the climate change and food security (CCFS) framework were developed to analyze how climate change affects food security outcomes for the four components of food security – food availability, food accessibility, food utilization, and food system stability – in various direct and indirect ways [19].

Climate change and `natural` disasters such as droughts, landslides, and floods greatly affect food security. Climate change variables influence biophysical factors, such as plant and animal growth, water cycles, biodiversity, and nutrient cycling and the ways in which these are managed through agricultural practices and land use for food production. However, climate variables also have an impact on physical/human capital – such as roads, storage and marketing infrastructure, houses, productive assets, electricity grids and human health – which indirectly changes the economic and socio-political factors that govern food access and utilization and can threaten the stability of food systems.

All these impacts manifest themselves in the ways in which food system activities are carried out. The framework developed by CCFS [19], illustrates how adaptive adjustments to food system activities will be needed all along the food chain to cope with the impacts of climate change.

The climate change variables considered under the framework are:

- The CO_2 fertilization effect of increased greenhouse gas concentrations in the atmosphere;
- Increasing mean, maximum and minimum temperatures;
- Gradual changes in precipitation: increase in the frequency, duration and intensity of dry spells and droughts; changes in the timing, duration, intensity, and geographic location of rain and snowfall;
- Increase in the frequency and intensity of storms and floods;
- Greater seasonal weather variability and changes in the start/end of growing seasons

As direct evidence, more frequent and more intense extreme weather events (droughts, heat, and cold waves, heavy storms, floods), rising sea levels, and irregularities in seasonal rainfall patterns (including flooding) are already having immediate impacts on not only food production, but also food distribution infrastructure, the incidence of food emergencies, livelihood assets and human health in both rural and urban areas [33].

The indirect impacts are expected to emanate from gradual changes in mean temperatures and rainfall. These will pose vital challenges to the suitability of land for different types of crops and pasture; the health and productivity of forests; the distribution, productivity, and community composition of marine resources; the incidence and vectors of different types of pests and diseases; the biodiversity and ecosystem functioning of natural habitats; and the availability of good-quality water for crop, livestock and inland fish production. The loss of arable land to increased aridity (and associated salinity), groundwater depletion, and sea-level rise. Uncontrolled internal and external migration, resource-based conflicts, and civil unrest triggered by climate change are a potential threats to future food systems [19]. The threat of climate change stands to jeopardize the livelihoods attached to the land, it is anticipated to drive more than 100 million people into extreme poverty by 2030. Adapting to the risk, along with the right technological support may provide a temporary solution [19,30].

A more comprehensive approach to dealing with food and nutrition security as adopted by TEEB [34], draws from how different disciplines are dealing with one of the most important challenges of the 21st century: the triple challenge of how to achieve food and nutrition security for a growing population, how to maintain or regenerate environmental integrity for the life-supporting services provided by the ecosystems of our planet and how to ensure that the ongoing transformation of global food systems supports social equality and equity and leaves no one behind. The fundamental design of TEEB Agri Food is to view it as a whole 'eco-agri-food system', from production to consumption, and to build bridges between disciplines and knowledge bases toward achieving goals for a common good. This new approach indicates the implications of the economic invisibility of nature in decision-making and seeks to throw light on the sizeable but hidden contributions of biodiversity and ecosystem services to social and economic wellbeing. This multidisciplinary approach to the issue of food systems can thus be summarized in Table 2.

Table 2: Simplified Food System Approach of TEEB.

Perspectives	Key Areas
1. Agronomist: feeding millions of growing populations	• Increased hunger due to political instability and conflicts • Double food production by 2050 • More yields with fewer resources • Agricultural specialization • Transformative change
2. Environmentalist: saving the planet	• Biodiversity loss • Deforestation • Freshwater withdrawals • GHG emissions • Climate change • Ecosystem conservation • Sustainable development of local community • Reducing poverty • Maintaining environmental integrity
3. Sociologist: sustainable rural livelihoods and social equity	• Farming/ agricultural labor • Insecure livelihoods • Urbanization-poverty reduction • Poor developmental policy • Inclusive rural transformation • Infrastructure development for better preserving/marketing • Food distribution schemes • Policies that address key social equity and justice
4. Economist: efficient markets for cheap food	• Provide cheap and affordable food for all • Pay insufficient attention to the constraints of natural capital stock • Produce more crops the cheapest way possible, in order to remain competitive on the global market • Maximize the net welfare of economic activities • Sacrifices food quality, perpetuates inequalities and contributes to the rise of food and agriculture-related disease
5. Health Specialist: healthy diets	• The shift from primarily infectious to non-communicable diseases (cardiovascular and obesity) • Malnutrition a global health burden/emergency • Changing dietary decisions, more appropriate to climate change

Source: TEEB 2018 [34].

As TEEB [34] succinctly relates how every one of us on the planet is faced with the universal challenge to sustainably and equitably produce healthy food in a world of scarcity and uncertainty. The neglect of the environment and social problems caught the attention which led to emphasizing the mode of preventive measures in the 2015 Paris Agreement and now the 2030 Agenda and its Sustainable Development Goals (SDGs) milestones, necessitating an inter-disciplinary dialogue at best. This practice is made mandatory by policymakers who could chalk out a way from the current crisis.

Current food security and climate change

As already pointed out earlier, the relationship between food, the environment, and climate change, gained prominence since the Rio Declaration followed by the Paris Agreement. Also, the prominence of food has been well considered by the IPCC by incorporating it in its Fifth Assessment Report [24] and the Special Report on global warming of 1.5 °C [25].

Until recently, the impacts of climate change have been understood largely as a problem of the future that will benefit from advanced planning. A key finding of AR5 is that climate change impacts on food security are happening now. Moreover, these impacts are not evenly distributed – tropical areas that are most exposed to increasing climate risks are also home to a large proportion of the world's food-insecure poor people [35].

Food systems in AR5, SR15 and the Paris agreement

The Rio Declaration was the first to have initiated a relationship between food, environment, and climate change, which has been also reconsidered under the Paris Agreement [36]. The obtrusive fact of including food in the IPCC Fifth Assessment Report [24] and the Special Report on global warming of 1.5 °C (SR15), gives evidence of the prominence food has gained in the recent past [25].

The importance of the food system approach can be well conceived in the shift of focus of working group (WG)II from climate change to agricultural production (crops, livestock, and agriculture) as well as directing attention to undernourished people. This strategy was adopted to emphasize the urgency for research on the benefits derived from potential innovations in food processing, packaging, transport, storage and trade. Food security vulnerability for both rural and urban dwellers too has been considered under socio-economic and cultural aspects and lack of food access respectively.

The IPCC Special Report on global warming of 1.5 °C comes with a warning of increasing the risk of food insecurity if the temperature is not contained well below 2 °C [37].

Food systems and the Paris agreement: The Paris Agreement put forward a temperature target of limiting warming to well below 2 °C and pursuing efforts to limit warming to 1.5 °C. Under the Paris Agreement, Parties are expected to put forward their best efforts through nationally determined contributions (NDCs) [11,36], and to strengthen these efforts in the years ahead. Article 2 of the Agreement makes clear the agreement is within 'the context of sustainable development' and states actions should be 'in a manner that

does not threaten food production' to ensure food security, which as proposed can be achieved through carbon dioxide removal (CDR) and the use of bioenergy. All these are expected to come at large investments and abrupt land use changes will be required to advance bioenergy with carbon capture and sequestration (BECCS), afforestation and reforestation (AR) and biochar technologies, which will in turn impact food security emanating from competing demands for land between climate change mitigation and food production.

Climate change and food security

Potential effects on food availability and production: Food availability is determined by the physical quantities of food that are produced, stored, processed, distributed, and exchanged. FAO [19], has quantified national food balance sheets and adequacy is assessed through a comparison of availability with the estimated consumption requirement for each food item. Climate change affects agriculture and food production in complex ways. Alterations in the agroecological environment directly impact food production and indirectly growth and distribution of incomes and therefore demand agricultural produce. Land suitability will be in turn affected by changes in temperature and precipitation, due to continued emissions of greenhouse gases, affecting crop yields.

Based on the findings from the Special Report on Emission Scenarios (SRES) of the Intergovernmental Panel on Climate Change [25], which clearly expressed the effects of future climate change on global food supply under different socio-economic development, expressed in terms of population and income level. Varying trends in population growth and economic development will impact future climate change and simultaneously the responses of agriculture to changing climate conditions at regional and global scales.

Considering the SRES emission scenario and Representative Concentration Pathways (RCP) climate models, the global mean surface temperature is projected to rise in a range from 1.8 °C (with a range from 1.1 °C to 2.9 °C for SRES B1) to 4.0 °C (with a range from 2.4 °C to 6.4 °C for A1) by 2100. It will bring about significant benefits to agriculture in the temperate latitudes, the areas potentially suitable for cropping will expand so also the growing period with a rise in crop yields. Humid and temperate grasslands may increase grassland productivity hence reducing the burden on stall feeding. These gains have to be set against an increased frequency of extreme events such as heat waves and droughts in the Mediterranean region and heavy precipitation and storms in the coastal regions. With temperature increases, the same climate models predict increased evapotranspiration and lower soil moisture levels in drier areas leaving some cultivated areas unsuitable for cropping and tropical grassland increasingly arid. It is feared this will expand the range of agricultural pests and increase the ability of pest populations to survive the winter and attack spring crops. Atmospheric carbon dioxide concentration is set to increase (SRES emission scenario), which is a big influencer for agriculture.

An increase in atmospheric carbon dioxide (CO_2) concentrations, is another important factor for agriculture. Experimental yield response to elevated carbon dioxide shows that under optimal growth conditions, crop yields increase at 550 ppm CO_2 in the range of 10% to 20% for C3 crops (such as wheat, rice and soybean) and only 0–10% for C4 crops such as maize and sorghum. It is thus envisaged that higher CO_2 concentrations will have a positive effect on many crops, enhancing biomass accumulation and final yield, but their nutritional quality is doubtful. Some cereal and forage crops show lower protein concentrations under elevated carbon dioxide conditions [20].

Potential impact on food access: Access to food involves the ability to obtain food, including the ability to purchase food at affordable prices. In many countries, the ratio of the cost of a minimum daily food basket to the average daily income is used as a measure of poverty [19]. When this ratio falls below a certain threshold, it signifies that food is affordable and people are not impoverished; when it exceeds the established threshold, food is not affordable and people are having difficulty obtaining enough to eat. This criterion is an indicator of chronic poverty, and can also be used to determine when people have fallen into temporary food insecurity, owing to reduced food supply and increased prices, a sudden fall in household income, or both [19].

Declining food availability caused by climate change is likely to lead to increased food costs impacting consumers globally through higher prices and reduced purchasing power, with low-income consumers, particularly at risk from higher food prices. Higher prices depress consumer demand, which in turn will not only reduce energy intake (calories) globally but will also likely lead to less healthy diets with lower availability of key micronutrients and increase diet-related mortality in lower and middle-income countries. These changes will slow progress toward the eradication of malnutrition in all its forms [20].

As the energy intake is reduced this may expand the risk of hunger which has been variably represented by the global economic models, but all models project an increase in the risk of hunger due to climate change [20].

Food often travels very long distances, and this has implications for costs [38,39]. Increasing fuel costs could lead to more expensive food and increased food insecurity. The growing market for biofuels is expected to have implications for food security, because crops grown as feedstock for liquid biofuels can replace food crops, which then have to be sourced elsewhere, at a higher cost [19].

Impacts of climate change on food utilization: Food utilization involves the nutrient composition of food, its preparation, and the overall state of health. Food safety and quality affect food utilization. Climate change will also affect

the ability of individuals to use food effectively by altering the conditions for food safety and changing the disease pressure from vector, water, and food-borne diseases [11,20].

Food utilization has been conceptualized in various ways. Food utilization is concerned with the household's treatment of the food as well as the biological processes of food utilization, which pertain only to an individual's biological capacity to make use of food for a productive life. The Food and Agriculture Organization (FAO) describes food utilization as simply "the way in which the body makes the most of various nutrients in the food" [19]. Food utilization is typically measured with indicators of nutritional status. Utilization can be considered the final step toward reaching adequate nutritional status. It has been established that with stable availability of and access to food, proper utilization of food then leads to adequate nutrition [40].

Malnutrition can be attributed to food insecurity. A great proportion of the world's population about 75% is rural and added that the urban poor, are unable to meet the prescribed dietary needs to satisfy the nutritional requirements. Destruction of natural food sources has led to the decline of wild foods, and limits on small-scale horticultural production due to scarcity of water or labor resulting from climate change could affect nutritional status adversely. An indirect impact of climate change on nutrition will be felt due to reduced income and capacity to purchase a diversity of foods to maintain a balanced dietary need [19].

Climate change impact on food safety and human health: Exposure to climate change is characterized by changing weather patterns (more intense and extreme events) and indirectly through changes in water, air, food quality and quantity, ecosystems, agriculture, livelihoods, and infrastructure [24]. This direct and indirect exposure can cause death, disability, and suffering. Physical illness increases vulnerability and reduces the capacity of individuals and groups to adapt to climate change. A sick population is most unlikely to cope with stresses of any kind, most importantly those posed by climate change.

Both acute and chronic nutritional problems Table 3, are associated with climate variability and change, its complex and involve different pathways [41,42] (regional water scarcity, salinization of agricultural lands, destruction of crops through flood events, disruption of food logistics through disasters, and increased burden of plant infectious diseases or pests [38]. Micronutrient deficiencies arise from diminished dietary diversity which reduces overall food consumption. Malnutrition increases the risk both of acquiring and dying from an infectious disease. Studies from Asia and Africa suggest that lack of food was associated with an increase in mortality and diseases which may have been prevented with timely public health measures.

However, a major implication of climate change on public health emanates from rural to urban migration consequent upon the loss of livelihoods [43]. Population displacement can lead to increases in communicable diseases and poor nutritional status resulting from overcrowding, and a lack of safe water, food and shelter [19,44].

Table 3: Prevalence of Undernourishment (PoU) in the World, 2005-2018.

	Prevalence of undernourishment (%)					
	2005	2010	2015	2016	2017	2018
World	14.5	11.8	10.6	10.7	10.8	10.8
Africa	21.2	19.1	18.3	19.2	19.8	19.9
Northern Africa	6.2	5.0	6.9	7.0	7.0	7.1
Sub-Saharan Africa	24.3	21.7	20.9	22.0	22.7	22.8
Eastern Africa	34.3	31.2	29.9	31.0	30.8	30.8
Middle Africa	32.4	27.8	24.7	25.9	26.4	26.5
Southern Africa	6.5	7.1	7.8	8.5	8.3	8.0
Western Africa	12.3	10.4	11.4	12.4	14.4	14.7
Asia	17.4	13.6	11.7	11.5	11.4	11.3
Central Asia	11.1	7.3	5.5	5.5	5.7	5.7
Eastern Asia	14.1	11.2	8.4	8.4	8.4	8.3
South-eastern Asia	18.5	12.7	9.8	9.6	9.4	9.2
Southern Asia	21.5	17.2	15.7	15.1	14.8	14.7
Western Asia	9.4	8.6	11.2	11.6	12.2	12.4
Western Asia and Northern Africa	8.0	7.1	9.2	9.5	9.8	9.9
Latin America and the Caribbean	9.1	6.8	6.2	6.3	6.5	6.5
Caribbean	23.3	19.8	18.3	18.0	18.0	18.4
Latin America	8.1	5.9	5.3	5.5	5.7	5.7
Central America	8.4	7.2	6.3	6.1	6.1	6.1
South America	7.9	5.3	4.9	5.3	5.5	5.5
Oceania	5.5	5.2	5.9	6.0	6.1	6.2
Northern America and Europe	< 2.5	< 2.5	< 2.5	<2 .5	< 2.5	< 2.5

Source: FAO 2019 [56].

The global population is expected to reach 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100, depending upon a range of plausible future trends in fertility, mortality, and international migration [45]. According to FAO, undernourishment occurs when an individual's habitual food consumption is insufficient to provide the amount of dietary energy required to maintain a normal, active, healthy life. Apart from insufficient calories ('hunger'), undernourishment occurs in terms of nutritional deficiencies in vitamins (e.g., vitamin A) and minerals (e.g., iron, zinc, iodine), so-called 'hidden hunger'. Hidden hunger tends to be present in countries with high levels of undernourishment, but micronutrient deficiency can occur in societies with a low prevalence of undernourishment. However, in many parts of the world, poverty is linked to poor diets (FAO 2018). This may be through a lack of resources to produce or access to food in general, or healthy food, in particular, as healthier diets are more expensive than diets rich in calories but poor in nutrition. The relationship between poverty and poor diets may also be linked to unhealthy 'food environments,' with retail outlets in a locality only providing access to foods of low nutritional quality– such areas are sometimes termed 'food deserts'. Although there is a range of methods to assess food insecurity, they all have some shortcomings. For example, the FAO has developed the Food Insecurity Experience Scale

(FIES), a survey-based tool to measure the severity of overall households' inability to access food. While it provides reliable estimates of the prevalence of food insecurity in a population, it does not reveal whether actual diets are adequate or not with respect to all aspects of nutrition [11].

The prevalence of disease can be expected to occur in countries lacking a proper food monitoring and surveillance system, therefore unable to detect environmental and chemical contamination, hence increasing the risk to public health through acute and chronic exposure to contaminants. As WHO projects that such changes may increase the mortality to 250,000 deaths per year between 2030 and 2050. In addition, 500,000 deaths per year have been calculated as a consequence of changes in diet and body weight due to climate change by 2050 [46].

Food safety is increasingly at risk with increasing temperatures. As has been confirmed that with rising temperatures, there has been a linear increase in the occurrence of common forms of food poisoning such as salmonellosis [17,42]. Similarly, shellfish poisoning has been associated with algal blooms. Warmer seas may thus contribute to increased cases of human shellfish and reef fish poisoning (ciguatera) and poleward expansions of these disease distributions. Climate change can result in the grain being harvested with more than 12% to 14% moisture level required for stable storage, which increases the risk for fungal growth and mycotoxin formation. These compounds can have serious health effects and sometimes are even fatal [4,19,20,44,46].

Another example of the implications that climate change can have for food safety is the methylation of mercury and its subsequent uptake by fish and human beings, as observed in the Faroe Islands [44].

Therefore, a higher percentage of the world's population is predicted to be at risk of undernourishment due to global climate change, under the SRES A1B scenario by a further 21% for 2050, 19% for 2085 and 17% for 2100. In absolute terms, this represents an additional 1.7 billion people at risk of undernourishment due to climate change by 2050, 1.3 billion by 2085, and 1.1 billion by 2100, with the number varying only slightly between climate models [32].

Impacts on the stability of food supplies: Climate-induced events such as floods and droughts will be more frequent and extreme due to climate change [47]. These create critical threats to the stability of food systems, especially for households with limited capacity in their food consumption [48]. With increasing frequency, duration and intensity of extreme events, future global and regional weather conditions are also expected to become more variable. Both food supply and food security is vulnerable to fluctuations in crop yields [20].

Growing humanitarian crisis and destabilizing food supply is also a cause for concern in climate related migrations. People are forced to leave their homes due to increasing incidence of drought, giving rise to conflict over access to resources in the receiving area [19,23,43].

As drought and flood become more pronounced and widespread with climate variability, in semiarid and subhumid areas, it will dramatically reduce crop yields and livestock numbers and productivity. Geographically these are the poorest regions with highest level of undernourishment as in Sub-Saharan Africa and South Asia [48].

Another major factor influencing food distribution and stability is transportation. During periods of climate related disaster routes are disrupted and facilities cannot reach in time bringing the entire food trade or relief to a standstill. Such disturbances are felt more strongly in the developing countries who lack proper storage facility and infrastructure to support during an emergency. In addition, developing countries lack the monetary support and technological advancements necessary to help mitigate crisis to ensure constant production and supply of food for their people. To address the problem, a policy environment is needed that fosters freer trade and advocates investments in transportation, communications and irrigation, and self-preparedness [19,20,49,50].

The future of food security

Climate change and its impacts on demographic patterns, urbanization, population movements and changes in food consumption patterns intensify the food system risks globally [51]. Climate change has come to impact food security through various routes. The direct impact has come to be felt on crop yields and indirectly on the availability of water and quality, pests and diseases and pollination [49]. The changing concentration of carbon dioxide in the atmosphere has affected biomass and nutritional quality, also there are risks involved in transport and storage facilities.

The food system encompass been prevented with timely public health measures es all the activities and actors in the production, transport, manufacturing, retailing, consumption, and waste of food, and their impacts on nutrition, health and well-being, and the environment. Activities linked to food production has rendered the once productive arable land infertile and unusable, due to excessive use of artificial fertilizers, coupled with the effects of deforestation. Thus, it can be seen that food production systems, the effects of climate change and food security are all closely linked and integrated, as changes to one system can lead to substantial effects on the other systems [50].

The impact which the food system has come to bear on the climate can be distinctly described under 'food miles' [39], the total distance food travels from the original production site to its place of consumption. For most cases, higher food miles

would equate to greater GHG emissions as more fossil fuels are required to be combusted for transportation purposes. Thus, food supplies that are transported overseas via air freight often account for a high amount of GHG emissions. Contribution of the various transport means have been estimated to be as: air transport contributes 1.093 CO_2 equivalent/t/km, truck transport contributes 0.15 CO_2 equivalent/t/km and rail transport at 0.01 CO_2 equivalent/t/km [39,50].

Pressure of urbanization and ever-growing population, is a major threat to the climate as more and more land needs to be cleared to both housing and feeding the ever-increasing millions [52]. Many countries around the world are dependent on food imports for feeding their population. This can be best exemplified by the Amazon fires and devastation of the rainforest, the life support for the planet to feed populations in China (soyabean) and cattle ranching to meet the beef demand for USA [53]. With rising world population and an approximation of two-thirds of the world being urbanized by 2050, the carbon footprint associated with the transportation of food has increased from 11% [54] to current rate of 26% of global GHG emissions [55-57].

Conclusion

The growing threat of climate change to the global food supply and the challenges it poses for food security and nutrition, requires urgent concerted policy responses and the deployment of all the scientific knowledge and accumulated evidence available. From a food security perspective, the most immediate risks arising because of climate change are from extreme events. Climate change impact on food safety and public health are closely related to effects on food security and on nutrition, and therefore cannot be dealt separately. Both are emergent properties of the food system, resulting from the interaction of many dynamic factors in ways that resist simple linear projection.

To provide practical guidance to decision-makers at either the community or national level, there is a need to first develop conceptual frameworks that can explain how food security and climate change work within complex food systems ensuring human health and wellbeing.

1. From this perspective, a more focused approach to research on food security and availability and the sustainability issues linked to food production and distribution can be undertaken in the future: Recognizing the factors that directly and indirectly affect food security

2. A more focused approach to food availability to the poor countries who are dependent on food imports

3. An interdisciplinary strategy to tackle the issue of food insecurity will provide a broader view of food insecure sectors, while taking into account its intricate social, economic and environmental components.

References

1. Cook J, Nuccitelli D, Green SA, Richardson MM, BarbelWinkler B, Painting R, Way R, Jacobs P, Skuce AA. Quantifying the Consensus on Anthropogenic Global Warming in the Scientific Literature, Environmental Research Letters. 2013; 8:024024. doi:10.1088/1748-9326/8/2/024024,https://iopscience.iop.org/article/10.1088/1748-9326/8/2/024024/pdf

2. UNFCCC. Open Letter by the Executive Secretary on COVID-19. UN Climate Statement. 23April 2020.

3. Ziervogel G, Ericksen PJ. Adapting to Climate Change to Sustain Food Security, Wiley Interdisciplinary Reviews Climate Change. 2010. DOI: 10.1002/wcc.56, https://www.researchgate.net/publication/227604047

4. FAO. Climate Change: Unpacking the Burden on Food Safety. Food Safety and Quality Series No. 8. Rome. 2020. https://doi.org/10.4060/ca8185en, http://www.fao.org/3/ca8185en/CA8185EN.pdf

5. McGuigan C. Reynolds R, Wiedmer D. Poverty and Climate Change: Assessing Impacts in Developing Countries and the initiatives of the International Community, London School of Economics ConsultancyProjectfor The Overseas Development Institute. 2002. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/3449.pdf

6. Global Humanitarian Overview (GHO). United nations Coordinated Support to People Affected by Disaster and Conflict, OCHA Geneva, Switzerland. 2020. https://www.humanitarianresponse.info/

7. Kundzewicz ZW. Extreme Weather Events and TheirConsequences, Papers on Global Change IGBP. 2016; 23(1). DOI: 10.1515/igbp-2016-0005

8. Preston BL, Jones RN. Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions. CSIRO. 2006. https://www.cmar.csiro.au/e-print/open/prestonbl_2006a.pdf

9. OECD. Climate Change: Helping Poor Countries to Adapt, Development Co-operation Report 2010. https://www.oecd-ilibrary.org/

10. FAO. Climate Change and Food Systems: Global Assessments andImplications for Food Security and Trade. Food Agriculture Organization of the United Nations (FAO). 2015.

11. Mbow C, Rosenzweig LG, Barioni TG. Food Security. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. 2019. [PR. Shukla, J Skea, E Calvo Buendia, V Masson-Delmotte, HO Pörtner, DC Roberts, P Zhai, R Slade, S Connors, R van Diemen, M Ferrat, E Haughey, S Luz, S Neogi, M Pathak, J Petzold, J Portugal Pereira, P Vyas, E Huntley, K Kissick, M Belkacemi, JMalley, (eds)].

12. Calicioglu O, Flammini A, Stefania Bracco S, Bellù L, Sims R. The Future Challenges of Food and Agriculture: An Integrated Analysis of Trends and Solutions, Sustainability. 2019; 11:222. doi:10.3390/su11010222, https://www.mdpi.com/journal/sustainability

13. Kanamaru H. Food Security under a Changing Climate, Bulletin n°: WMO. 2009; 58(3). https://public.wmo.int/en/bulletin/food-security-under-changing-climate

14. Tacoli C, Bukhari B, Fisher S. Urban Poverty, Food Security and Climate Change, International Institute for Environment and Development, Human Settlements Working Paper No.37, Rural – Urban Interactions and Livelihood Strategies. 2013. https://pubs.iied.org/pdfs/10623IIED.pdf

15. Fraanje W, Lee-Gammage S. What is food security? (Foodsource: building blocks). Food Climate Research Network, University of Oxford. 2018. https://foodsource.org.uk/

16. Simon AS. Food Security: Definition, Four Dimensions, History, Basic Readings as an Introduction to Food Securityfor students from the IPAD Master, SupAgro, Montpellierattending a joint training programmein

Rome from 19th to 24th March2012, University of Roma Tre. 2012. http://www.fao.org/fileadmin/templates/ERP/uni/F4D.pdf

17. Tirado MC, Clarke R, Jaykus LA, McQuatters-Gollop A, Frank JM. Climate Change and Food Safety: A Review, Food Research International. 2010; 43:1745–1765. https://doi.org/10.1016/j.foodres.2010.07.003

18. Phillips WR. FAO: its Origins, Formation and Evolution 1945-1981, Food and Agriculture Organization of United Nations, Rome. 1981. http://www.fao.org/3/a-p4228e.pdf

19. FAO. Climate Change and Food Security: A Framework Document. 2008. http://www.fao.org/forestry/15538079b31d45081fe9c3dbc6ff34de4807e4.pdf

20. Schmidhuber J, Tubiello FN. Global food security under climate change. Proc Natl Acad Sci U S A. 2007 Dec 11;104(50):19703-8. doi: 10.1073/pnas.0701976104. Epub 2007 Dec 6. PMID: 18077404; PMCID: PMC2148361.

21. Berry EM, Dernini S, Burlingame B, Meybeck A, Conforti P. Food security and sustainability: can one exist without the other? Public Health Nutr. 2015 Sep;18(13):2293-302. doi: 10.1017/S136898001500021X. Epub 2015 Feb 16. PMID: 25684016.

22. Jarosz L. Defining World Hunger, Scale and Neolibral Ideology in International Food Security Policy Discourse, Food Culture and Society An International Journal of Multidisciplinary Research. 2011; 14: 1. https://www.researchgate.net/publication/233557133

23. Ingram J. A Food Systems Approach to Researching Food Security and its Interactions with Global Environmental Change, Food Security. 2011. DOI 10.1007/s12571-011-0149-9

24. IPCC. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of theIntergovernmental Panel on ClimateChange. [Field, CB Barros,VR Dokken, DJ Mach KJ, Mastrandrea MD, Bilir T, Chatterjee M, Ebi KL, Estrada YO, Genova,RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL.(eds.)]. Cambridge University Press, Cambridge,UnitedKingdom and New York, NY, USA. 2014.. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf

25. IPCC. 'Global warming of 1.5°C: Summary for Policy Makers.' Intergovernmental Panel on Climate Change. IPCC: United States. 2018. https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_High_Res.pdf

26. Garnett T, Benton T, Nicholson W, Finch J. Overview of Food System Challenges (Foodsource: chapters). Food Climate Research Network, University of Oxford. 2016. https://foodsource.org.uk/sites/default/files/chapters/pdfs/foodsource_chapter_1.pdf.

27. Guzman OEM. Food Security and Population Growth in the 21st Century, E-International Relations. 2011. https://www.e-ir.info/2011/07/18/food-security-and-population-growth-in-the-21st-century/

28. Gopinath G. The Great Lockdown: Worst Economic Downturn Since the Great Depression, IMF Blogs, Insights and Analysis on Economics and Finance. 2020. https://blogs.imf.org/

29. United Nations, Department of Economics and Social Affairs, Population Division, World Population Prospects 2019: Ten Key Findings. 2019. https://population.un.org/

30. Godfray HC, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C. Food security: the challenge of feeding 9 billion people. Science. 2010 Feb 12;327(5967):812-8. doi: 10.1126/science.1185383. Epub 2010 Jan 28. PMID: 20110467.

31. Ray DK, West PC, Clark M, Gerber JS, Prishchepov AV, Chatterjee S. Climate change has likely already affected global food production. PLoS One. 2019 May 31;14(5):e0217148. doi: 10.1371/journal.pone.0217148. PMID: 31150427; PMCID: PMC6544233.

32. Dawson,PT, Perryman,NA, Osborne T. Modelling Impacts of Climate Change on Global Food Security, ClimaticChange. 2014; 134(3):1-12. DOI: 10.1007/s10584-014-1277-y http://link.springer.com/article/10.1007%2Fs10584-014-1277-y (DOI 10.1007/s10584-014-1277-y)

33. Beer T. The Impact of Extreme Weather Events on Food Security. In: Mal S., Singh R., Huggel C. (eds) Climate Change, Extreme Events and Disaster Risk Reduction. Sustainable Development Goals Series. Springer, Cham, Switzerland. 2018. DOI: 10.1007/978-3-319-56469-2_8

34. The Economics of Ecosystems and Biodiversity (TEEB). Measuring What Matters in Agriculture and Food Systems: A Synthesis of the Resultsand Recommendations of TEEB for Agriculture and Food's Scientific and Economic Foundations Report. Geneva: UN Environment. 2018.

35. Vermeulen SJ. Climate Change, Food Security and Small-Scale Producers. CCAFS Info Brief. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. 2014. www.ccafs.cgiar.org

36. Meadu V, Coche I, Vermeulen S, Friis AE., The Paris Climate Agreement: What it Means for Food and Farming, Climate Change Agriculture and Food Security. 2015. https://cgspace.cgiar.org/

37. Allen MR, Dube OP, Solecki W, Aragón-Durand F, Cramer W, Humphreys S, Kainuma M, Kala J, Mahowald N, Mulugetta Y, Perez R, Wairiu M, Zickfeld K. Framing andContext. In: Global Warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V, P Zhai, HO Pörtner, D Roberts, J Skea, PR Shukla A. Pirani W. Moufouma-Okia C. Péan R. Pidcock S. Connors JBR. Matthews Y. Chen, X Zhou, M.I. Gomis, E

38. Hammond ST, Brown JH, Burger JR, Flanagan TP, Fristoe TS, Silva NM Nekola JC, Okie JG. Food Spoilage, Storage, and Transport: Implications for a Sustainable Future, BioScience. 2015; 65:758-768. doi:10.1093/biosci/biv081, https://watermark.silverchair.com/

39. Coley D, Howard M, Winter M. Local Food, Food Miles and Carbon Emissions: A Comparison of Farm Shop and Mass Distribution Approaches, Food Policy. 2009; 34:150–155. doi:10.1016/j.foodpol.2008.11.001 https://getmoreeducation.org/

40. Aberman LN, Tirado C. Impacts of Climate Change on Food Utilization, Chapter from book Global environmental change. 2014;717-724. https://www.researchgate.net/publication/278652699_Impacts_of_Climate_Change_on_Food_Utilization

41. UNFCCC. Human Health and Adaptation: Understanding Climate Impacts on Health and Opportunities for Action, Subsidiary Body for Scientific and Technological Advice, Forty-Sixth Session, Bonn, Germany. 2017. https://unfccc.int/sites/default/files/resource/docs/2017/sbsta/eng/02.pdf

42. Smith KR, Woodward A, Campbell-Lendrum D, Chadee,DD, Honda Y, Liu Q, Olwoch JM, Revich B, Sauerborn R. Human Health: Impacts, Adaptation, and Co-Benefits. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field CB, VR Barros, DJ Dokken, KJ Mach, MD Mastrandrea, TE. Bilir, M Chatterjee, KL Ebi, YO Estrada, RC. Genova, B Girma, ES Kissel, AN Levy, S MacCracken, PR Mastrandrea, LL White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2014. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5Chap11_FINAL.pdf

43. Debucquet DL, Martin W. Implications of the Global Growth Slowdown for Rural Poverty, Agricultural Economics. 2018; 49. https://onlinelibrary.wiley.com/doi/epdf/10.1111/agec.12419

44. Confalonieri U, Menne B, Akhtar R, Ebi KL, Hauengue M, Kovats RS, Revich B, Woodward A. Human Health, Climate Change Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the

FourthAssessment Report of the Intergovernmental Panel on Climate Change, ML Parry, OF Canziani, JP Palutikof, PJ van derLinden and CE Hanson, Eds., Cambridge University Press, Cambridge, UK. 2007; 391-431.

45. United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019: Highlights (ST/ESA/SER.A/423). https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf

46. WHO. Food Safety, Climate Change and Role of WHO,Department of Food Safety and Zoonoses. 2018. https://www.who.int/foodsafety/_Climate_Change.pdf

47. Kundzewicz ZW, Mata LJ, Arnell NW, Doll P, Kabat P, Jiménez B, Shiklomanov IA. Freshwater Resources and Their Management. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson (Eds.), Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment report of theIntergovernmental Panel onClimate Change. Cambridge, UK. 2007; 173–210.

48. Firdaus RB, Gunaratne MS, Rahmat SR, Kamsi NS. DoesClimate Change only Affect Food Availability? What Else Matters? Cogent Food & Agriculture. 2019; 5:1; 1707607. https://doi.org/10.1080/23311932.2019.1707607, https://www.tandfonline.com/doi/pdf/10.1080/23311932.2019.1707607?needAccess=true

49. Myers SS, Smith MR, Guth S, Golden CD, Vaitla B, Mueller ND, Dangour AD, Huybers P. Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. Annu Rev Public Health. 2017 Mar 20;38:259-277. doi: 10.1146/annurev-publhealth-031816-044356. Epub 2017 Jan 6. PMID: 28125383.

50. Islam MS, Wong AT. Climate Change and Food In/Security: A Critical Nexus, Environments. 2017; 4(2):38. https://doi.org/10.3390/environments4020038, https://www.mdpi.com/2076-3298/4/2/38/pdf

51. Jahn M, Jayamaha B, Mulhern WS, Ross DE, Rose MA, Treverton GF. Global Food System Stability and Risk: At the Nexus of Defense and Development. Thomson Reuters. 2018. https://www.thomsonreuters.com/content/dam/ewp-m/documents/ thomsonreuters/en/pdf/reports/global-food-systemstability-and-risk-0718.pdf

52. Janetos A, Justice C, Jahn M, Obersteiner M, Glauber J, Mulhern W. Pardee Center Research Report, The Risks of Multiple Breadbasket Failures in the 21st Century: A Science Research Agenda. 2017. http://www.bu.edu/pardee/files/2017/03/Multiple-Breadbasket-Failures-Pardee-Report.pdf

53. Gola C. The Food Crisis and Food Security: Towards a New World Food Order? International Development Policy | Revue internationale de politique de développement. 2010; 1:215-232.

54. Wakeland W, Cholette S, Venkat K. Food transportation issues and reducing carbon footprint, JI Boye and Y Arcand (eds.), Green Technologies in Food Production and Processing, Food Engineering Series, Springer. 2012. DOI 10.1007/978-1-4614-1587-9_9,

55. Poore J, Nemecek T. Reducing food's environmental impacts through producers and consumers. Science. 2018 Jun 1; 360(6392):987-992. doi: 10.1126/science.aaq0216. Erratum in: Science. 2019 Feb 22;363(6429): PMID: 29853680.

56. FAO. The State of Food Security and Nutrition in the World. 2019. www.fao.org/state-of-food-security-nutrition/en/

57. Tan H. A Food Crisis Looms as Coronavirus Forces Farms to Stay Idle and Countries Hoard Supplies, CNBC. 30 March 2020. https://www.cnbc.com/2020/03/30/coronavirus-food-crisis-looms-as-farms-idle-countries-hoard-supplies.html