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Mitigating Climate Change for Food Security

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ABSTRACT: *Climate change brings a cascade of risks from physical impacts to ecosystems, agroecosystems, agricultural production, food chains, incomes and trade, with economic and social impacts on livelihoods and food security and nutrition. The people who are projected to suffer the earlier and the worst impacts from climate change are the most vulnerable populations, with livelihoods depending on agriculture sectors in areas vulnerable to climate change. Understanding the cascade of risks, as well as the vulnerabilities to these risks, is essential to frame ways to adapt. Reducing vulnerabilities is key to reducing the net impacts on food security and nutrition and also to preventing long-term effects. Increasing resilience of food security in the face of climate change calls for multiple interventions, from social protection to agricultural practices and risk management. Crops, livestock and seafood are major contributors to the global economy. Agriculture and fisheries are especially dependent on climate. Thus, elevated temperatures and carbon dioxide levels can have large impacts on appropriate nutrient levels, soil moisture, water availability and various other critical performance conditions. Changes in drought and flood frequency and severity can pose severe challenges to farmers and threaten food safety. In addition, increasingly warmer water temperatures are likely to shift the habitat ranges of many fish and shellfish species, ultimately disrupting ecosystems. In general, climate change will probably have negative implications for farming, animal husbandry and fishing. The effects of climate change must be taken into account as a key aspect along with other evolving factors with a potential impact on agricultural production, such as changes in agricultural practices and technology; all of them with a serious impact on food availability and price. This research is intended to provide critical and timely information on climate change and its implications in the food production/consumption system, paying special attention to the available mitigation strategies.*

KEYWORDS: *Mitigating, Climate, Change, Food, Security*

I. INTRODUCTION

Ending hunger, achieving food security and improving nutrition are at the heart of the sustainable development goals (Lal, 2004). At the same time, climate change is already impacting agriculture and food security and will make the challenge of ending hunger and malnutrition even more difficult. The effects of climate change on our ecosystems are already severe and widespread, and ensuring food security in the face of climate change is among the most daunting challenges facing humankind. While some of the problems associated with climate change are emerging gradually, action is urgently needed now to allow enough time to build resilience into agricultural production systems. Despite considerable progress, almost 800 million people are chronically undernourished, 161 million under-five year olds are estimated to be stunted.

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At the same time 500 million people are obese and 2 billion lack the essential micronutrients they need to lead healthy lives. Population and income increase as well as urbanization are driving increased in changing food and feed demand. FAO estimates that, in order to satisfy the growing demands driven by population growth and diet changes, food production will have to increase by at least 60% in the next decades.

Despite the considerable progress made during the last several decades in reducing hunger, as of 2015, almost 800 million people are chronically undernourished. An estimated 161 million children under five years old are stunted. At the same time, 500 million people are obese. It is not enough to have sufficient food produced globally to meet demand – enough food is produced globally now but there are still almost 800 million hungry people – but everybody has access to it, in the right quantity and quality, all the time. According to the United Nations, in 2015, there were still 836 million people in the world living in extreme poverty (less than USD1.25/day).

And according to the International Fund for Agricultural Development (IFAD), at least 70% of the very poor live in rural areas, most of them depending partly (or completely) on agriculture for their livelihoods (FAO, 2008).

It is estimated that 500 million smallholder farms in the developing world support almost 2 billion people, and in Asia and sub-Saharan Africa these small farms produce about 80% of the food consumed. Climate change threatens to reverse the progress made so far in the fight against hunger and malnutrition. As highlighted by the latest assessment report of the Intergovernmental Panel on Climate change (IPCC), climate change augments and intensifies risks to food security for the most vulnerable countries and populations.

Four out of the eight key risks induced by climate change identified by the IPCC have direct consequences for food security:

- Loss of rural livelihoods and income
- Loss of marine and coastal ecosystems, and livelihoods
- Loss of terrestrial and inland water ecosystems, and livelihoods
- Food insecurity and breakdown of food systems

The earliest and the more impacted are the most vulnerable countries and populations, including in arid and semi-arid areas, landlocked countries and small island developing states. Climate change will also have broader impacts through effects on trade flows, food markets and price stability and could introduce new risks for human health. More efforts to respond to climate change are needed immediately to safeguard the capacity of food systems to ensure global good security (IPCC, 2013).

Climate change generates considerable uncertainty about future water availability in many regions. It will affect precipitation, runoff and snow/ice melt, with effects on hydrological systems, water quality and water temperature, as well as on groundwater recharge. In many regions of the world, increased water scarcity under climate change will present a major challenge for climate adaptation. Sea-level rise will affect the salinity of surface and groundwater in coastal areas.

Climate change is likely to affect the frequency and intensity of extreme events. The magnitude of the impacts of extreme events on agriculture is already high. FAO's recent analysis of 78 post-disaster needs assessments in 48 developing countries spanning the 2003–2013 period shows that 25% of all economic losses and damages inflicted by medium and large-scale climate hazards such as droughts, floods and storms in developing countries affect the agriculture sectors. Impact translates from climate to the environment, to the productive sphere, to economic and social dimensions, bringing a range of additional risks on the availability of food, on access to food and utilization of food, as well as on the stability of these characteristics, for both farm and non-farm households (FAO, 2011).

At the farm/household level, climate change impacts may reduce income level and stability, affecting productivity, production costs or prices. Such variations can drive sales of productive capital, such as cattle, which reduces long-term household productive capacity. At the national level, exposure to climate risks can trigger shocks on agricultural production and food availability, with dangers of market disruptions, effects on supply and storage systems, and increases in agricultural commodity prices (food and feed), impacting accessibility and stability of food supplies for the entire population, particularly in countries with significant shares of the population spending a large part of their income on food. This triggers macro-economic effects for countries for which agriculture is an important part of GDP and/or constitutes an important source of employment. Climatic risks can also hinder agricultural development by discouraging investments (Abbas, 2018). At global level, climatic shocks impacting areas of global importance for food supplies can have remote impacts through effects on: (i) supply flows and food price spikes, with increased market volatility; and (ii) impacts on bilateral contracts and/or import/export behaviour, with disruption of trade patterns. Food price volatility is likely to be exacerbated by climate change. Trade is expected to play a major role in adjusting to climate-change-driven shifts in agricultural and food production patterns (HDR, 2019). Recent experience indicates that climate change effects on food price volatility are greatly influenced by domestic policies, with export bans contributing to price fluctuations. Ultimately, global markets will not be accessible to the poorest countries and the poorest populations without sufficient purchasing power (ARD, 2014).

Finally, we must underline that food production is a substantial contributor to greenhouse gas emissions and a source of environmental degradation. Hence, it can magnify and accelerate climate change. Farming contributes about 15% of global greenhouse gas emissions —roughly as much as transport. More pessimistic assessments claim that the overall contribution of food production to atmospheric emissions can reach 30%. Therefore, effectively restricting the long-terms effects will require making food production more resistant to the climate and the achievement of significantly lower carbon footprints. Countries and their citizens suffer unequally the threat of food supply. Some countries, which lose arable land and fisheries, lack the resources to maintain food security at a reasonable cost. Others are more vulnerable to unfavourable international trade agreements. Finally, regional conflicts disrupt food distribution (Lal, 2004).

1.1 Reduced Yields

According to Chang (2004), crop and livestock productivity may diminish by elevated temperatures, drought-related stress or increased CO_2 concentrations. Their effects on crops and livestock may arise suddenly or gradually. These events can be faced before, during and after the disaster. Risk, threat and vulnerability are three inter-connected concepts. *Risk* is a combined measure of probability and degree of harm of a territory and its inhabitants being affected by natural hazards. It follows equation:

$$\text{Risk} = \text{Threat} \times \text{Vulnerability} \quad (1)$$

Threat is the probability of a natural hazard to occur to a certain extent, and with a certain intensity and duration. The human factor has no impact on threat. Finally, vulnerability is associated to the social impact of an adverse phenomenon and must thus, be properly managed in order to avoid or reduce the unwanted effects of natural events and their associated risks. For this reason, risk is usually assessed for prevention (to prevent hazards in order to alleviate, diminish or avoid their potential damage). Extreme climate events, such as droughts, floods, and too high or low temperatures, can have unwanted effects on crops including corn, soybean, wheat and small grains, rice, cotton, pasture, and fruits (Aryal *et al.*, 2019).

Several strategies for crops and livestock have been devised to increase their resilience to extreme climates. Therefore, crops can be managed by breeding for drought and temperature tolerance, adjusting loads and irrigation, pruning canopies, using particle films and shading, and selecting appropriate cultivars (Sofi *et al.*, 2019). In turn, livestock can be managed by selecting better breeds; improving nutrition during periods of high heat load; using sunshades, evaporative cooling or mechanical ventilation; using rotational grazing to minimize damage to range and pasture; optimizing forage stock management and reducing herd size during drought periods (Angulo *et al.*, 2013). Water can be managed by installing more efficient irrigation systems or increasing the efficiency of existing ones; storing water in ponds and tanks; rationalizing water use to avoid wastage; and facilitating livestock access to water. In any case, the most effective way of reducing vulnerability and its associated risks is by improving access to information (e.g. with early warning systems), fostering R&D activities, and developing risk management, regional outreach, extension and education programs for farmers.

1.2 Increased Irrigation

The impact of irrigation on the environment is felt mainly in the quantities of available crop, soil and water, and in their quality. The effects arise mainly from changes in hydrological conditions caused by irrigation schemes. A number of world regions currently rely heavily on rain-fed agriculture and require abundant irrigation, which has increased cultivation costs and raised conflicts over access to water. This situation has promoted unwanted environmental problems arising from quantity and quality changes in soil and water (Dai *et al.*, 2020). A few studies have addressed the effects of global warming on agricultural water use including changes in net irrigation, water demand and water uptake by crops. This is especially important because agriculture is the greatest user of fresh water, irrigation accounts for 70% of all water used globally each year (Woznicki *et al.*, 2015).

Climate projections have been used to estimate water demand for future irrigation which are estimated to increase between 40% and 250% depending on the crop at the end of this century. The increased requirements have been ascribed to reduce water availability in the growing seasons, evapotranspiration and changes in crop phenology. This causes great uncertainty about the predictions in the literature (Woznicki *et al.*, 2015).

1.3 Particular Cases and Approaches

In a recent study, Ellioft, *et'al*. (2014) investigated global warming effects on yield variability in maize, sorghum and soybean between 1968 and 2013 in the USA. The temperature trend in the studied period had a beneficial effect on maize but an adverse impact on sorghum and soybean. On the contrary, the precipitation trend had a positive effect on the three crops. Precipitation rise had significant positive sensitivity for almost all counties under non-irrigated conditions.

This means that all rain fed crop yields are benefitted by any increase in precipitation. For irrigated crops, relatively lesser proportion of counties show positive sensitivity, and with lower magnitudes than non-irrigated conditions, with increase in precipitation. Irrigated land exhibited considerably increased robustness, and even more effective mitigation of the climate impacts. Examined the effects of water stress on crop production over the 1996–2015 period, in various regions of China. They suggest that using the water footprint to assess the suitability of irrigation in order to implement water resources management policies, irrigation and the most effective crop variety worldwide. This would be the best way to achieve a viable adaptation of crops to environmental changes. The advent of powerful computational resources has facilitated the monitoring and implementation of more effective solutions for the increased irrigation demand.

The effects of irrigation on the water table and on soil salinity, drainage and groundwater, and those of mitigation strategies, can currently be simulated and predicted by using agro-hydro-salinity models such as SaltMod. Such models have allowed the effects of climatic conditions on agriculture to be predicted before they occur. Sun *et al*. (2019), identified, for areas of northern China, the best practices of water management and fertilization with N for summer cucumber in the greenhouse. They calibrated and validated models constructed from experimental data (applied to 240 scenarios with different water uses and various fertilization conditions) using environmental and economic indices to determine the best management practices (Ashour, 2012).

Aronsson *et al.* (2016), used remote sensing and a Geographical Information System (GIS) to conduct a spatial and temporal study over the 1950–2013 period in Saudi Arabia. For this purpose, they collected information about evapotranspiration and modelled crop coefficients as a function of a 16-day time-series Moderate Resolution Imaging Spectro-radiometer normalized difference vegetation index. They used the information thus obtained to simulate daily evapotranspiration with the model of soil water balance and aggregated it to the monthly and annual evapotranspiration figures.

1.4 Reducing Carbon Emissions by Fishing Industries

Global fish production from capture and culture operations also contributes to the global CO_2 emissions. Although overall fish production is relatively energy-efficient relative to other high-quality animal protein production on land, there is still place for further reduction in energy use and gas emissions. The vessel and gear used in capture fisheries are two major users of energy. Thus, in stationary gear fisheries, vessels travelling to and from fishing grounds often use large amounts of energy, and so does resistance from the fishing gear in mobile gear fisheries of the trawling or dredging type. Shore-side facilities should take advantage of maturing renewable energy systems such as those based on wind and solar power. In aquaculture, intensive production of finfish and crustaceans, which relies heavily on feeds and aeration, is the greatest source of greenhouse gas emissions. Integrated food production systems such as those of fish and rice or shrimp and mangrove can substantially reduce such emissions from aquaculture systems. Fishery management has a strong impact on all aspects of fish production (especially in capture fisheries), and can thus influence fuel use efficiency (Badiola *et al.*, 2018).

II. MITIGATION STRATEGIES

Existing guidelines for food control remain valid in the face of the potential additional challenges posed by climate change-related phenomena (FAO, 2008). Different issues are particularly relevant in order to identify emerging risks as soon as possible. Such issues are detailed explained below.

- **Interdisciplinarity**

Food safety involves the whole process of food production, from pre-production to the final product. Therefore, food safety assurance is a complex task. Recommendations associated to food safety generally underline the necessity of an extensive input and coordination, and this is a challenging task in many countries. Animal and plant health, environment and food hygiene are interconnected aspects expectedly affected by climate change. Therefore, food safety challenges involve a preparation and understanding in an interdisciplinary context. Furthermore, the large implications of climate change on public health and food safety have complex consequences (Badiola *et al.*, 2018).

- **Application of Good Practices**

The national programs of good practices on hygiene, agriculture, animal husbandry, veterinary care and aquaculture are crucial for defining management strategies towards climate change. Nevertheless, such guidelines have to be engineered taking into account the impact of changes on the prevalence and occurrence of microbiological and chemical hazards, as well as on insects, pests and their vectors. The development of guidelines on these issues requires the development of high standard applied research to support the different approaches proposed to solve the problem. To this aim, a continuous update of guidelines is crucial, as soon as novel knowledge is created. However, for a successful implementation of this, a compromise of governments and industrial associations is a determining factor (Badiola *et al.*, 2018).

- **Monitoring and Surveillance – Food and the Environment**

An early identification of potential problems entails an integrated monitoring of both food and environmental changes because it enables the implementation of solutions. Although such programs are implemented in different countries, such surveillance requires a continuous revision of emerging hazards associated to global climate change. The data produced by such programs can be very useful to improve predictive modelling and risk assessment, so they should be easy to share nationally and internationally. At an international level, relevant information can be circulated through networks such as INFOSAN (the International Food Safety Authorities Network). This network provides a mechanism for exchanging information on routine and emerging food safety issues. A need clearly exists to focus research efforts on the development of expeditious methods for detecting pathogens and contaminants in complex sample matrices such as foods in order to facilitate a rapid response to the results of monitoring and surveillance programs. (FAO, 2008).

- **Disease Surveillance – Human and Animal**

Monitoring the epidemiology is critical in public health, not only for an early identification of emerging diseases, but also to implement strategies for their control. For this reason, an efficient epidemiological monitoring requires a close collaboration of professionals dealing with human and animal health, as well as those focused on environmental issues. In this regard, a quick investigation of unusual outbreaks is critical. The International Health Regulations provides a management program for coordinating events associated to climate change that could lead to international health emergencies, also providing assistance for their detection, notification. One Health is an emerging global key concept integrating human and animal health through international research and policy. The complex relationships between the human and animal have resulted in a human-animal-environment interface since prehistorical times. People, animals, plants, and the environment are so intrinsically linked that prevention of risks and the mitigation of effects of crises that originate at the interface between humans, animals, and their environments can only improve health and wellbeing. The “One Health” approach has been successfully implemented in numerous projects around the world. The containment of pandemic threats such as avian influenza and severe acute respiratory syndrome within months of outbreak are few examples of successful applications of the One Health paradigm (Gondim *et al.,* 2012).

- **Predictive Modelling**

Different predictive models have been developed to foresee the probability of a given outcome to occur. Some of the have been defined to evaluate how the climate change can affect ecological systems and lead to emerging hazards. The marine sector has used such models in combination with meteorological, oceanographic and remote sensing information to predict harmful algal blooms. Because accuracy in the predictions depends on the amount of data available and on their quality, international collaboration is essential in developing accurate models. In addition, as climate-associated changes are the more and more complex, the development of predictive models requires sustainable accomplishments and continuous international cooperation (Asplen *et al.,* 2015).

- **Risk Assessment**

Risk assessment gives a scientific background to develop and adopt food safety standards, as well as other food safety actions. The effects of climate change can lead to novel food safety risks, which in turn determine novel priorities in risk assessment. For instance, if mixtures of mycotoxins appear more frequently in crops, then the maximal accepted concentrations should be revised. New mycotoxin occurrence frequency and level data from monitoring and surveillance programs could also influence decisions on appropriate limits at the national or international level. A group of Joint FAO/WHO experts has set up risk assessment on contaminants, pesticides, veterinary drug residues, food additives and microbiological hazards. Furthermore, another group of experts from Joint FAO/WHO was designated to deal with emerging issues as they arise. All the countries members of WHO and FAO can propose the prioritization of risk-assessment at an international level. Moreover, these countries have access to risk assessment guidance on emerging hazards arising from climate change. International risk assessment mechanisms should be established and experts trained in developing countries to understanding how risks must be assessed in order to make informed decisions on their local applicability in the light of new data obtained from their own monitoring and surveillance programs (FAO, 2011).

- **Early Warning and Emergency Response Systems**

Improved early warning systems are fundamental to reduce the risk posed by climate change-related natural disasters and emergencies on the lives and livelihoods of vulnerable people. This requires close cooperation among the veterinary, food safety and public health sectors at both the national and the international level. Emergency preparedness is also essential. Countries should review their existing food safety emergency plans and develop new ones. They should review and update other disaster and emergency plans to ensure that food safety management issues are appropriately dealt with in those situations (Autret *et al.,* 2016).

- **Strengthened Dialog with the Public**

Food safety should be assured through effective control measures at every step along the food chain. Since one-third of food produced in developing countries is lost before consumption, and due to high moisture contents in storage promote spoilage and production of mycotoxins, the “dry chain”, which is initial drying with storage in water-proof containers, is proposed as an effective control technology. Other new drying and storage technologies make implementation of the dry chain feasible to minimize mycotoxin accumulation and insect infestations in dry products, reduce food loss, improve food quality, safety and security, and protect public health. If consumers are to play their intended role, they should be aware of the hazards associated with some foods and of the relevant control measures. Consumers’ education is therefore essential and governments have a role to play here. The public does not properly understand some hazards, such as those posed by mycotoxins, as they represent an essentially invisible threat that is difficult to publicize effectively. Informing the public about typical foods susceptible to mycotoxin contamination, and about their risks to public health, might help reduce the use and trade of substandard food in hard times (Chen *et al.,* 2011).

- **New Technologies**

A number of scientific and technological innovations are expected to play a major role in helping us understand and deal with the food safety challenges posed by climate change. Such innovations include new nano-based filtering devices capable of removing a wide range of chemical and microbiological contaminants from water or even soils. They also include rapid pathogen and contaminant detectors relying on novel techniques (nano-technologies included); new molecular biological methods such as nucleic acid sequence comparisons and genomics-based approaches to characterizing complex microbial communities and their interactions; and the use of genetically modified crops suitable for growth on marginalized land. Although countries will differ in their capacity to participate in the development of the new scientific and technological advances, all should strive to be up to date with new developments so that they can efficiently exploit the new opportunities and, possibly, influence the prioritization of research investments. Special attention should be given by each individual country to the development of capacities and mechanisms for assessing and managing environmental and food safety risks potentially associated to the use of the new technologies. As noted above, FAO/WHO continue to develop guidance on genetically modified food safety assessments. In addition, they intend to hold an expert meeting on the potential food safety implications of nanotechnology applications in the food and agriculture sectors (FAO, 2011).

- **Investing in Scientific and Technical Capacities**

Some of the above-discussed issues share a common theme, namely: the need for applied research to provide a better understanding of problems and for new approaches to dealing with them. The ability to use science to find solutions relies on prior investments in developing human resources. Many developing countries will require more careful planning to encourage the development of the competence needed to address pressing problems. In many cases, it is already possible to make better use of existing competence at the national level by fostering relationships among government services, universities and private sector associations, among others. Carefully assessing food safety capacity building requirements by national authorities is also essential for optimal training and education through technical assistance from interested donors and international organizations (Chen *et al.,* 2011).

- **International Dimension**

The whole issue of climate change is a global concern (Arias *et al.,* 2008), so international bodies should play a major role in assuring that all of its dimensions are properly dealt with. As noted earlier, a need exists to share data and information obtained from food safety and disease monitoring and surveillance systems that international networks could help fulfil. Regional and international cooperation on selected research areas of common interest would probably afford better outputs from existing resources (Angulo *et al.,* 2013). The international community should have timely access to scientific advice to guide their management choices as new food safety risks emerge. Since climate change can cause food safety risks to occur, it would be useful to devise ways to make mechanisms for providing scientific advice more responsive to increased and unscheduled demands. The Joint Global Initiative for Food-Related Scientific Advice (GIFSA), which was jointly established by FAO and WHO, should address this need at least in part. GIFSA aims to facilitate transparent fund mobilization to facilitate the organization of expert meetings on critical food safety issues requested by Codex or by FAO and WHO member countries. The food safety challenges raised by climate-related changes have highlighted the need for continued emphasis on food safety capacity building in developing countries. Coordination among donor agencies and international organizations providing technical assistance in this area remains a central issue (FAO, 2011).

III. CONCLUSION

Although agriculture has always been at the mercy of unpredictable weather, today is even more vulnerable. Warmer temperatures may increase crop yields in some regions, but climate change is expected to have adverse overall impacts leading to reduced food supplies and increased food prices. Sub-Saharan Africa and South Asia are already experiencing high rates of food insecurity, and are predicted to see the greatest declines in food production. Elevated levels of atmospheric carbon dioxide are expected to lower the levels of zinc, iron and other important nutrients in crops. With changes in rainfall patterns, farmers face dual threats from flooding and drought.

Flooding washes away fertile topsoil on which farmers depend for productivity, whereas droughts dry soil out and make it easier to blow or wash away. Elevated temperatures increase the water requirements of crops and make them more vulnerable in dry periods. Some species of weeds, insects and other pests benefit from elevated temperatures and carbon dioxide levels, which increase their potential to damage crops and create financial hardship among farmers. A shifting climate also facilitates expansion of agricultural pests to new areas (US Global Change Research Program, 2009). With higher temperatures, most of the world's glaciers have begun to recede; this has affected farmers who depend on glacial melt water for irrigation (IPCC, 2013). Rising sea levels are increasing flood risks for coastal farms and boosting salt-water intrusion into coastal freshwater aquifers —thus making these water sources too salty for irrigation. Climate change is also expected to have an impact on ecosystems and the services they provide to agriculture (*e.g.*, pollination, pest control by natural predators).

Many wild plant species used in domestic plant breeding are threatened by extinction. Food system activities, including food production and transport, and food waste storage in landfills, produce greenhouse gas emissions that contribute to climate change. Livestock, which is the greatest contributor, accounts for an estimated 14.5% of global greenhouse gas emissions from human activities and meat from ruminants is especially emission-intensive. World leaders have agreed that the average global temperature should not rise by more than 2 °C above pre-industrial levels if the most catastrophic climate change scenarios are to be avoided.

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