IMPACT OF CLIMATE CHANGE ON FOOD SECURITY: AN OVERVIEW

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ABSTRACT

There are roughly 1 billion food insecure people in the world today, each having this status because food is unavailable to them, because it is unaffordable, or because they are too unhealthy to make use of it – or some combination of the three. Assessing the potential effects of climate change on food security requires understanding the underlying determinants of these three aspects of food security – availability, access, and utilization – and how climate change might affect each. This paper explores these aspects and determinants of food security, summarizing the basic mechanisms by which climate change might impact the lives of the global food insecure.

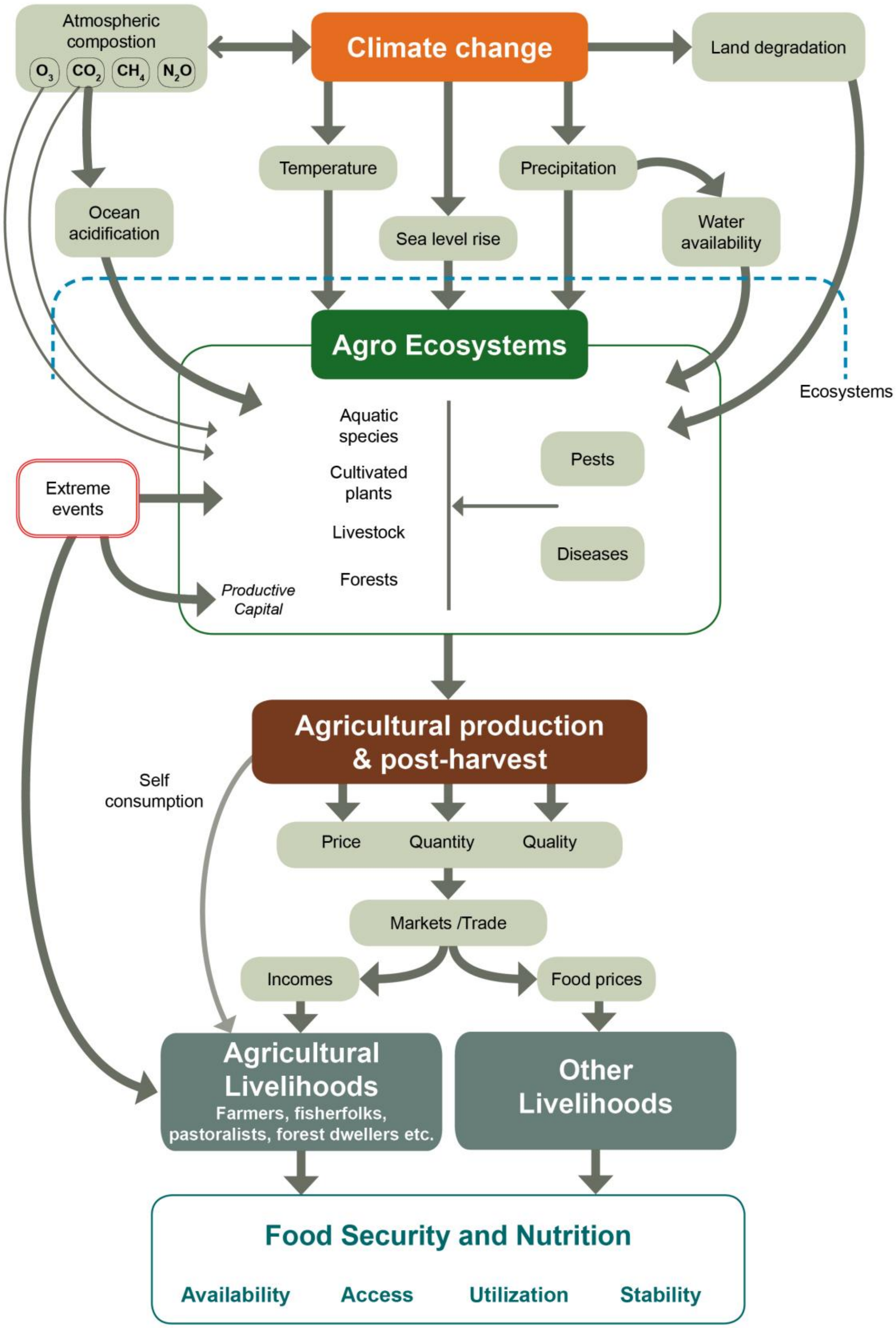
Key Words: *Food Security, Insecure, Utilization.*

INTRODUCTION

Climate change is profoundly impacting the conditions in which agricultural activities are conducted. In every region of the world, plants, animals, and ecosystems are adapted to the prevailing climatic conditions. When these conditions change, even slightly, even in a direction that could seem more favourable, the plants and animals present will be impacted, some will become less productive, or even disappear. Some of these impacts can be easily predicted, like the direct impact of a heat wave on a specific plant at a specific moment of its growth (provided that it has been well studied enough). Others are more complex to predict, like the effect of a certain climatic change on a whole ecosystem, because each element will react differently and interact with the other. For instance, many cultivated plants react favourably, in controlled conditions, to an increase of CO_2 in the atmosphere. But at the same time many weeds also react favourably. The result, in the field, can be an increase or decrease in yield of the cultivated plant depending on weeds competing for nutriments and water and on remedial agricultural practices. Pests and diseases are likely to move, following climate change, thus arriving in areas less prepared to them, biologically and institutionally, with potentially higher negative impacts.

These additional risks on agricultural production directly translate into additional risks for the food security and nutrition of the people who directly depend on agriculture for their food and livelihood. They can also have an impact on the food security and nutrition of distant populations through price volatility and disrupted trade. As shown in Figure 1, there is thus a cascade of risks from climate changes to agro-ecosystems, to agricultural production, to economic and social consequences and finally to food security and nutrition.

This paper aims to show the multiple links through which climate change impacts food security and nutrition. It starts from knowledge about climate change itself, with a focus on recent knowledge improvements that are of major interest for the agriculture sectors. It then briefly recalls some of the main known impacts on crops, livestock, forestry, fisheries and aquaculture. The paper analyses the economic and social consequences of these impacts on agricultural production. The fourth section focuses on vulnerabilities (biophysical, social, institutional) to better understand the links leading from climate change to negative impacts on food security and nutrition, in order to be able to identify means to address them.



Atmospheric compostion
O3 CO2 CH4 N2O
Climate change
Land degradation
Temperature
Precipitation
Ocean acidification
Sea level rise
Water availability
Agro Ecosystems
Ecosystems
Aquatic species
Cultivated plants
Livestock
Forests
Pests
Diseases
Extreme events
Productive Capital
Agricultural production & post-harvest
Self consumption
Price
Quantity
Quality
Markets /Trade
Incomes
Food prices
Agricultural Livelihoods
Farmers, fisherfolks, pastoralists, forest dwellers etc.
Other Livelihoods
Food Security and Nutrition
Availability
Access
Utilization
Stability

This Figure shows the schematic representation of the cascading effects of climate change impacts on food security and nutrition. A range of physical, biological and biophysical impacts bear on ecosystems and agro-ecosystems, translating into impacts on agricultural production. This has quantity, quality and price effects, with impacts on the income of farm households and on purchasing power of non-farm households. All four dimensions of food security and nutrition are impacted by these effects.

IMPACTS ON AGRO-ECOSYSTEMS

Climate change can have both direct and indirect impacts on agricultural production systems. We qualify here as direct impacts those that are directly caused by a modification of physical characteristics such as temperature levels and distribution along the year and water availability on a specific agricultural production. Indirect effects are those that affect production through changes in other species such as pollinators, pests, disease vectors, invasive species. Direct effects are easier to predict because they can be simulated and/or easily modelled. They are now quite well projected for main staple crops. There are fewer confirmed results for many plants, livestock and aquaculture. Indirect effects, which can play a major role, particularly in less controlled environments such as for forestry and fisheries, are much more difficult to model given the high number of interacting parameters and links, many of which are often not known yet. In some cases, to predict impacts, either a reference to a comparable system under the predicted climate or to the observation of the impacts of a comparable climate change on another system can be of use.

Crops

The observed effects of past climate trends on crop production are evident in several regions of the world with negative impacts more common than positive ones, including several periods of price spikes following climate extremes in key producing regions. There is evidence that climate change has already negatively affected wheat and maize yields in many regions and also at global level. The increased frequency of unusually hot nights in most regions is damaging for most crops, with observed impacts on rice yields and quality.

Several methods and many distinct crop models and model types can be used to estimate how future climate change will affect crop production. Convergent research results from globally consistent, multimodel climate change assessment for major crops with explicit characterization of uncertainty show that climate change will fundamentally alter global food production patterns. Negative crop productivity impacts from climate change for wheat, rice and maize – everything else being equal given present day agricultural areas, levels of management and technology – are expected in low-latitude and tropical regions, even at low levels of warming.

Impacts in the mid to high latitudes are expected to be more mixed, especially at lower levels of warming .Some high-latitude regions are expected to benefit – sometimes substantially – from warmer temperatures and longer growing seasons; however, other environmental conditions, such as soil quality issues in the far north, will likely constrain expansion. Spatial differences are also observed at regional and sub regional scales, particularly where there are substantial differences in elevation. Contrasted impacts between high- and low-latitude regions indicate that climate change is likely to exacerbate existing imbalances between the developed and developing world. Overall climate change will also increase variability in crop yields in many regions.

Effects of temperature are generally well understood up to the optimum temperature for crop development. Effects above these optimum temperatures are much less known. Studies also show a large negative sensitivity of crop yields to extreme daytime temperatures around 30 °C to 34 °C depending on the crop and region.

The effect of climate change on crop yield will depend on many parameters: temperature, precipitation patterns and atmospheric CO2 increase given the stimulatory effect of elevated atmospheric CO2 on plant growth (increasing the rate of leaf photosynthesis and improving the efficiency of water use) in most cases, especially for C3 crops like wheat and rice. There are uncertainties related to the interactions between CO2, nitrogen stress and high temperature effects. The response of crops is genotype-specific. Recent results also confirm the damaging effects of elevated tropospheric ozone on crop yields, with estimates of losses for soybean, wheat and maize in 2000 ranging from 8.5 to 14 percent, 4 to 15 percent, 2.2 to 5.5 percent, respectively.

The recent consolidated study on the impact of global climate change on agriculture, conducted in the framework of the Agricultural Model Intercomparison and Improvement Project (AgMIP) and Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP), finds that by 2100 the impact of climate change on crop yields for high-emission climate scenarios ranges between –20 and –45 percent for maize, between –5 and –50 percent for wheat, between –20 and –30 percent for rice, and between –30 and –60 percent for soybean. Assuming full effectiveness of CO2 fertilization, climate change impacts would then range between –10 and –35 percent for maize, between +5 and –15 percent for wheat, between –5 and –20 percent for rice, and between 0 and –30 percent for soybean. If nitrogen limitations are explicitly considered, crops show less profit from CO2 fertilization and amplified negative climate impacts.

A recent multimodel study using IPCC's high scenario of end-of-century radiative forcing of 8.5 W/m2 found a mean effect on yields of four crop groups (coarse grains, oil seeds, wheat and rice, accounting for about 70 percent of global crop harvested area) of –17 percent globally by 2050 relative to a scenario with unchanging climate. The hypothesis for this multimodel assessment combined the most extreme radiative forcing scenario with an assumption of limited CO2 fertilization effects in 2050, but has not included the deleterious effects of increased ozone concentrations and biotic stresses from a range of pests and diseases, nor the likelihood of increased occurrence of extreme events.

Major agricultural producers in temperate zones, such as the European Union for wheat or the United States of America for maize, can be subject to strong negative impacts of climate change, due to: reduced water availability during the growing season; more frequent and intense heat events, which are most damaging during flowering and accelerated phenology, which can lead to reduced biomass production. However, these regions also tend to have more flexibility for adaptation.

Maize, sorghum and millet occupy the highest crop areas for all of Africa, but with considerable variation across regions. An International Food Policy Research Institute (IFPRI) climate change impact study on crop yields shows significant geographical variation of impacts, indicating that, while most direct climate change impacts will be negative, there will be positive impacts on yields in some areas with projected increases in precipitation, and in some elevated areas that will be able to be cultivated due to warmer temperatures.

Several studies based on coupling climate and crop models indicate that the agro-ecological potential of the grain-producing zone of Central Eurasia may increase due to warmer temperatures, longer growing seasons, decrease of frosts and positive impact of higher atmospheric concentrations of CO2 on crops, while other modelling experiments project the decline of agricultural potential due to increasing frequency of droughts. Agro-ecological projections driven by climate change scenarios suggest that the grain production potential in Russian Federation, Ukraine and Kazakhstan may increase due to a combination of winter temperature increase, extension of the growing season, and CO2 fertilization effect on agricultural crops; however, the most productive semi-arid zone could suffer a dramatic increase in drought frequency.

Vulnerabilities Determine the Importance of the net Impact on Food Security and Nutrition

As shown above, climate change impacts directly agro-ecosystems, which in turn has a potential impact on agricultural production, which drives economic and social impacts, which impact livelihoods and food security. In other words, impact translates from climate to the environment, to the productive sphere, to economic and social dimensions. At each stage of this stress transmission chain, the impact is determined by the shock itself and vulnerability at the stage/level of the stressed system. The transmission of a stress can be amplified or reduced, depending on the vulnerabilities at each level of the system. Vulnerability can increase over time if systems/households face repeated shocks that steadily erode their base/assets. These mechanisms of transmission, and the role played by the various vulnerabilities at each level, are what determine the final impact on food security and nutrition.

The IPCC, in its synthesis report (IPCC, 2014a) notes that exposure and vulnerability are influenced by a wide range of social and economic factors and processes that have been incompletely considered to date, which make quantitative assessments difficult. It notes also that climate-related hazards exacerbate other stressors, with often negative outcomes for livelihoods, especially for people living in poverty. Both biophysical and social vulnerability are thus critical as one considers the impact of climate change on food security. Social vulnerability examines the demographic, social, economic and other characteristics of the population that affect their exposure to risk and their ability to respond to and cope with negative shocks. A social vulnerability lens is essential to understand why certain individuals, households or communities experience differences in impacts even when they are in the same geographic region.

Understanding food-security vulnerability to climate change is key to understanding net climate impacts on food security, but also to framing ways to adapt as when climate risks are given, means to reduce the net climate change impact goes by reducing vulnerabilities.

Food security vulnerabilities to climate change

The food systems on which food security depends are subject to risks of various nature. These risks can impact directly the four dimensions of food security and nutrition: agricultural production (availability), access to food (sufficient income), utilization (nutrition, quality), and stability). They include climatic risks themselves and, as shown above, many other risks that are, in turn, influenced by climate change, or that may combine with climate change-induced risks and have compensative, cumulative or amplifying effects.

The net impact of a climatic shock on food security depends not only on the intensity of the shock but also on the vulnerability of the food system (and its subcomponents, the relationships between them) to the particular shock, i.e. the propensity or predisposition of the system to be adversely affected (IPCC, 2012). Here we focus on the "food security vulnerability" to climate change, meaning the propensity of the food system to be unable to deliver food security outcomes under climate change.

Food security vulnerabilities to climate change encompass the environmental (productive), economic and social dimensions. IPCC (2014a) has further described situations of institutional vulnerability, pointing to the key role of governance to condition vulnerabilities. Table 4 compiles main food security related vulnerabilities to different climate hazards and changes as mentioned in IPCC, 2014b.

Each of these vulnerabilities will directly increase negative impacts, and potentially increase their consequences. In a given system, shocks in one dimension can spread into another dimension: for instance production shocks are transmitted in the economic and social domains. The same is true for vulnerability: vulnerability in one domain is often linked, or can trigger, vulnerability in another domain.

Vulnerability can be defined as vulnerability of "what" (here: the food system and its components) to "what" (here climate risks and all the sets of risks, or a change – such as influenced by climate change in the context that they shape existing risks. Obviously some characteristics of a system make it more or less vulnerable to a set of risks. A farm relying on a single crop is particularly vulnerable to a pest affecting the crop or to a price drop of the crop. On the contrary, a much diversified system is less vulnerable to both pests and price fluctuations affecting specifically one type of production. An area prone to water scarcity will be more impacted by a drought. A rainfed system in this area is more vulnerable to a drought than an irrigated one. Households totally dependent on rainfed agriculture are more vulnerable from an economic point of view to drought than households having other sources of income. If they have no assets they are more vulnerable to this reduction of income and will be more impacted, especially if there are no social protection systems. In other words, the impacts of a drought are transmitted from the biophysical dimension to the production system and finally households. This transmission can be amplified or reduced, depending on the policies and institutions that are in place.

The majority of the world's poor and food-insecure people are rural, with direct or indirect dependence on agricultural production and income for their livelihoods, and are thus directly exposed to any risk that would impact agricultural production.
Farmers, wage-workers and people working in the agriculture sectors, as well as their relatives, are more exposed to some health hazards such as vector-transmitted diseases as well as heat waves, all of which will be modified in intensity and frequency by climate change (WHO, 2014),

From the economic dimension of food security smallholders are particularly vulnerable because of their limited capacity to smooth consumption in the face of climate shocks, particularly generalized shocks that affect a majority of households in the same location. Any increase in climate extremes will exacerbate.

IMPACTS ON FOOD SECURITY AND NUTRITION

Climate change impacts food security in its four dimensions, described in Box: availability, access, utilization and stability, directly and indirectly. As noted by the IPC there is much less quantitative understanding of how non-production components of food security will be affected. A review of peer-reviewed journal papers on food security and climate change since 1990 showed that they were mainly about availability, 70 percent, access, utilization and stability being represented by 11.9 percent, 13.9 percent and 4.2 percent, respectively, of the papers. The authors propose several causes of this unequal representation: a focus on direct effects of climate change, on areas easier to investigate, including through analysing single factor changes rather than complex systemic interactions.
This section summarizes the main expected impacts of climate change on the four dimensions of food security.

AVAILABILITY

Impacts on major crop yields is probably the food security-related issue on which there are the most studies, with two decades of work since the global assessment of Rosenzweig and Parry (1994), including major studies by Parry, Rosenzweig and Livermore. Projections vary according to the scenario used, the model and time scale. There is, however, consistency on the main orientations: yields are more impacted in tropical regions than at higher latitudes and impacts are more severe with increased warming. Importantly, many of the areas where crop yields are expected to decrease are also areas that are already experiencing food insecurity (see Box 6). There are important limitations to these studies. As shown above, there are risks that are difficult to factor in such projections, like single weather events and impacts of pests. Moreover, they are limited to major crops and the

FOOD SECURITY

"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" (World Food Summit, 1996). This widely accepted definition points to the following four dimensions of food security:

Availability: The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid).
Access: Access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet. Entitlements are defined as the set of all commodity bundles over which a person can establish command given the legal, political, economic and social arrangements of the community in which they live (including traditional rights such as access to common resources).

Utilization: Utilization of food through adequate diet, clean water, sanitation and healthcare to reach a state of nutritional well-being where all physiological needs are met.

Stability: To be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). The concept of stability therefore refers to the availability, access and utilization dimensions of food security.

CONCLUSION

Climate change is already impacting, and will increasingly impact, food security and nutrition. Through effects on agro-ecosystems it impacts agricultural production, the people and countries depending on it and ultimately consumers through increased price volatility. The impacts of climate change on food security and nutrition are the results of climate changes themselves and of the underlying vulnerabilities of food systems. They can be described as "cascading impacts" from climate to biophysical, to economic and social, to households and food security. At each stage vulnerabilities exacerbate effects.

This leads to drawing some important conclusions;

- The first and the worst impacted are the most vulnerable populations (poor), with livelihoods vulnerable to climate change (depending on agriculture sectors), in areas vulnerable to climate change.
- Reducing vulnerabilities is key to reduce final impacts on food security and nutrition and also to reduce long-term effects.
- The first and main impacts on food security and nutrition will be felt through reduced access and stability for the most vulnerable.

From an agronomic perspective, favourable conditions for crops and other species will move geographically. Optimizing these conditions will thus require changing crops and other cultivated species, moving them. Even to benefit from potential positive effects, such as longer growing seasons in some cold regions, would, most of the time, require significant changes in agricultural systems and practices to effectively translate into production growth. Also, these changes of climatic conditions will go with changes of other biotic parameters (like pests and diseases), which can counteract the benefits of climatic changes.

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