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Developing countries amid environmental risks and food (in)security

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ABSTRACT

The problematic relationship between human beings and the natural environment is perhaps the hardest challenge of our time, which requires a unified commitment of scientists, academics, and policy makers. An increasingly stressed planet – characterized by ecosystems degradation, water scarcity, and climate change pressures – undermines several human activities and, above all, the human ability to feed the world, not only by constraining the production of food, but also by hindering its distribution for instance. The achievement of food security has been, and continues to be, a central issue in the public discourse, and although its conceptualization has changed throughout the years, the goal of eliminating hunger – especially critical in time of Covid-19 – together with improving nutrition, remains a huge global priority. However, current food systems are blamed for exacerbating the environmental crisis – mainly through high emission levels of greenhouse gases, land conversion, abuse of pesticides and fertilizers – and new approaches based on the need of a sustainability transition are emerging. The purpose of the dissertation is to explore, based on the most accredited statistical sources and literature on the subject, which countries are considered most at environmental risk, which ones are classified as most food insecure or at risk of food insecurity. A multitude of indicators were taken into consideration to analyze the relationships between the state of food insecurity and susceptibility to environmental risks and to identify, in the near future, the situations of greater exposure to the risk of food non self-sufficiency.

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ACRONYMS

ADER	Average Dietary Energy Requirement
AoA	Agreement on Agriculture
CAP	Common Agricultural Policy
CMCC	Euro-Mediterranean Center on Climate Change
CRI	Climate Risk Index
DES	Dietary Energy Supply
E^3CI	European Extreme Events Climate Index
ECMWF	European Center for Medium-Range Weather Forecasts
EIU	Economist Intelligence Unit
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FFA	Food Assistance For Assets
FIES	Food Insecurity Experience Scale
FSIN	Food Security Information Network
GDP	Gross Domestic Product
GFSI	Global Food Security Index
GFW	Global Forest Watch
HLPE	High Level Panel of Experts
IFAB	International Foundation Big Data and Artificial Intelligence for Human Development
IPC/CH	Integrated food security Phase Classification/ Cadre Harmonisé
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LMICs	Low- and Middle- Income Countries
MENA	Middle East and North Africa
OPHI	Oxford Poverty and Human Development Initiative
PoU	Prevalence of Undernourishment
PPP	Purchasing Power Parity
SDGs	Sustainable Development Goals
SPS	Sanitary and Phytosanitary
TBT	Technical Barriers to Trade
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International’s Children Emergency Fund
WFP	World Food Programme
WHO	World Health Organization
WRI	World Resources Institute
WTO	World Trade Organization

INTRODUCTION

In some parts of the world people live in wealth, prosperity, and well-being, while in many others a fundamental right such as food is not guaranteed at all. This situation not only persists but is expected to worsen in the years to come. Since 2014, the number of undernourished people worldwide has been increasing, and in 2019, as many as 690 million people were estimated to be undernourished (FAO et al., 2020). Future projections made prior to the outbreak of the Covid-19 pandemic predicted that by 2030 this number would exceed 840 million (FAO et al., 2020), but to date this number can reasonably be considered underestimated due to the unexpected socioeconomic effects of the pandemic. As food security is a multidimensional concept that includes food availability, access, utilization, and stability, it can be threatened as a whole when one of these dimensions is not guaranteed. What often happens is that – precisely because food systems are extremely complex – there is no single factor causing food insecurity, but a set of factors, even of a very different nature: together exacerbate unfavorable conditions for the achievement of food security. Climatic shocks and environmental pressures undoubtedly fall among the factors contributing to food insecurity and, considering that such episodes are expected to increase in number and frequency in the future, this must be a matter of concern.

In 2018 it was estimated that more than 80% of food insecure people lived in areas particularly exposed to climate-related natural disasters such as floods, droughts, and storms (World Food Programme, 2018). FAO et al. (2018) reported that in 2017 the average Prevalence of Undernourishment (PoU) was 3.2 percentage points higher in countries highly exposed to climatic shocks (such as heat, drought, floods, storms) than in those not exposed or minimally exposed to them. This happens because climate variability and extreme climatic events, combined with the depletion of land and water resources, impacts food security in all its dimensions. In particular, agricultural productivity suffer from the occurrence of extreme natural hazards and related events, and its decline impacts on the availability of food, in turn causing an increase in food prices. Rising food prices, especially when coupled with reduced incomes for those whose livelihoods depend on agriculture, in its turns hinders economic access to food. Also, physical access to food can be compromised by damage to infrastructure, which is critical to the distribution of food from fields and farms to markets. Finally, extreme events also impact on the quality of food, and consequently on its utilization and safety (FAO et al., 2018; FSIN, 2020).

With these premises, it is of fundamental importance to address the threats posed by climate-related natural events to the populations most exposed to them, especially those most food insecure, with the implementation of effective structural policies aimed at breaking the vicious circle of hunger.

In this context, a first step is to identify which are the areas to be considered most at risk from a double perspective: food insecurity and environmental risk. In particular, this latter has to be understood as the effects of natural disasters, but also as the availability and quality of the two fundamental productive factors, i.e., water and land.

The objective of this dissertation is precisely to identify which are the countries that to date can be considered most at risk in this regard. To do this, a research was conducted for the most significant indicators of food insecurity and environmental risks, from which it was possible to obtain an overall risk index for a selection of countries. There are two main elements that distinguish the index presented here from most of the tools used in the literature to assess food insecurity (FAO, 2020a; FSIN, 2020; Economist Intelligence Unit, 2019). The first is that it combines all the four dimensions of food security into a single index. The second is that it also incorporates an environmental risks category, based on the assumption that this aspect is crucial to any assessment of food insecurity risk.

First of all, it must be said that there are several tools and metrics used in the literature to identify the areas, or countries, most at risk of food insecurity, and all of them are important to analyse this multifaceted phenomenon. In most indicators, monitored to assess food insecurity, the trends capture one or more dimensions of food security. Among them, there is the Prevalence of Undernourishment (PoU), an indicator used by the Food and Agriculture Organization of the United Nations (FAO), that indirectly measures the access dimension, reporting the number of people whose food consumption is insufficient. There are the moderate- and severe- food insecurity indicators, developed by the FAO based on the Food Insecurity Experience Scale (FIES), which provides the number of people in a population who have difficulty in obtaining food in adequate quantity, and of sufficient quality. In addition, there are tools, such as the Integrated food security Phase Classification/Cadre Harmonisé (IPC/CH), to detect levels of acute food insecurity. The IPC/CH is a tool used by the Food Security Information Network and the Global Network Against Food Crises for the publication of the Global Report on Food Crises. This is a report released annually, which informs about sudden food crises that occur in emergency contexts, where one or more factors compromise access to food. In contrast, there are few indices that measure food security in its complexity, considering all its dimensions. One example is the Global Food Security Index (GFSI) developed by the Economist Intelligence Unit, which accounts for the availability, affordability, quality and safety of food. It also provides a version of the index including the risks to food systems from climate change and other environmental factors. However, this category of risk is not central to the calculation of the modified index, but only a factor of adjustment of the baseline one.

Instead, this dissertation presents an overall risk index that includes, in addition to the four dimensions of food availability, access, utilization and stability, the susceptibility of countries to environmental risks. The environmental risk category is not marginal in the calculation of the overall risk index – as is the case in the adjusted GFSI – but is a crucial component, as are the four dimensions of food security. This because environmental risks are, and will be even more in the future, important determinants of food insecurity, not separate and minor issues. The combination of the two risks into a single index allows to identify the countries at greater risk of food insecurity, especially from the perspective of the impact this may suffer due to environmental factors. In other words, the overall risk index developed here, by intersecting the countries most at environmental risks and those most at risk of food insecurity, enables to investigate if there are geographical patterns of overall risk and draw conclusions about the impact that environmental risks have on food security.

The first chapter covers the review of the literature on food security, and also illustrates the main complexities that characterize food systems. The second chapter investigates the interconnection between food systems and the natural environment. It points out the channels through which these two mutually influence each other, and clarifies the concept of vulnerability to environmental risk, exemplifying some strategies designed at the international level to reduce it. The third chapter reports the countries currently considered most at risk of food insecurity according to a set of indicators, some measuring individual dimensions of food security, others intended to capture food security as a whole, reporting the countries most affected by food crises. Similarly, based on research carried out on a set of indicators, the fourth chapter explores the countries most exposed to environmental risks of various kinds, such as floods, water stress, but also the loss of large areas of trees and forests. The fifth chapter, after a description of the data sources used and the methodology adopted, presents an index of overall risk to food insecurity and environmental risk. Based on the index scores obtained, it provides a ranking of a number of developing countries that at present, based on available data and according to the indicators selected, are most susceptible to both risks. The dissertation concludes by discussing the relevance of the results obtained with the construction of the overall risk index and comparing them with findings from other studies. Finally, some considerations are made about where efforts should be directed to reduce vulnerability to environmental risks and food insecurity in most endangered countries.

CHAPTER I.

FOOD SECURITY FROM BASIC PRINCIPLES TO INCRESING COMPLEXITY

Achieving food security is, by nature, a complex objective, as it requires accurate and in-depth knowledge and analysis of the interconnected dynamics that take place in the entire agri-food system. With this premise, this chapter aims firstly to review how the perception of the problem of food security has changed and how this has contributed to the development of the most widely accepted definition of food security at present. Because food security goes hand in hand with nutrition security and food safety, some insights into both concepts are provided. Subsequently, attention will be focused on the increasing complexity of modern food systems and, in particular, on the relationship with the natural environment, which influences, and in turn is influenced by, food systems. Finally, some considerations will be made on the role played by international trade and public policies in achieving food security.

1.1 The road to the 1996 definition of food security

The achievement of a universally agreed definition of *food security* has always been proved very difficult, firstly because the concept strongly depends on the socio-economic context and has evolved with it, but also because different perceptions of the issue exist. The very first effort to define the notion of food security was made by the United Nations (UN) Food and Agriculture Organization (FAO[1]) in 1974. In fact, in 1974 the UN hold the first *World Food Conference* in Rome and on that occasion governments stated that "every man, woman and child has the inalienable right to be free from hunger and malnutrition in order to develop fully and maintain their physical and mental faculties" (United Nations, 1975, p. 2). At that time, the world was experiencing a food crisis characterized by high volatility in both supplies and prices. Hence, unsurprisingly, food security was described as the "availability at all times of adequate world supplies of basic food stuffs, […], to sustain a steady expansion of food consumption in countries with low levels of per capita intake and to offset fluctuations in production and prices" (United Nations, 1975, p. 14). Therefore, global hunger was clearly associated with insufficient food production, and the roots of the problem were assumed to be on the supply side; for this reason, the focus was put on the improvement of agricultural productivity and on the stabilization of prices. However, some years later, it became clear that the

[1] The FAO is a specialized agency of the United Nations born in 1945 with the aim of addressing issues related to the field of food and agriculture.

physical *availability* of food at aggregate level did not guarantee that people were actually able to get the food they needed. Indeed, even though sufficient quantities of food were produced, severe food deprivation was still a concern for many people. In this context, Sen (1981) introduced the entitlement approach, providing deeper insights for the analysis of famines than those focused on the physical availability of food. In fact, the entitlement approach – which refers to "each person's entitlements to commodity bundles including food, and views starvation as resulting from a failure to be entitled to any bundle with enough food" (Sen, 1981, p.434) – emphasizes that starvation reflects a lack of people's entitlements to food, which in turn depends on personal ownerships and the existing exchange possibilities (Sen, 1981). Subsequently, in 1983 the FAO enlarged the food security definition by including the notion of physical and economic *access* to food. In those years the World Bank (1986) provided an additional piece to the food security picture, making a distinction between *chronic food insecurity* and *transitory food insecurity*. It stated that the former is a "continuously inadequate diet caused by the inability to acquire food" (World Bank, 1986, p.1), while the latter is a "temporary decline in a household's access to enough food that results from instability in food prices, food production or household incomes" (World Bank, 1986, p.1).

In addition to the importance of accessing food, the concept further evolved in later years when, in a context of increased trade liberalization, food safety concerns, consumers' food preferences and the nutritional content of food began to receive attention. Therefore, at the World Food Summit hold in 1996 governments finally acknowledged nutritional outcomes as an integral part of food security. They agreed that "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

Typically, four components of food security are identified with this definition, namely *availability*, *access*, *utilization*, and *stability*. While some have described the four dimensions as the pillars on which food security depends, others prefer to visualize a more integrated set of linkages, which starts from agricultural production that makes the availability of food possible, goes through the household's access to available food, and ends with the individual utilization (Berry et al., 2015). To conclude, the few lines hereafter summarize what each dimension represents in the whole food security picture drawn at the World Food Summit in 1996 (FAO, 1996).

> *Availability* refers to "the availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid)" (FAO, 2006, p.1). As outlined above, the physical production and supply of food is necessary but not sufficient to ensure that people are food secure, since there must be adequate access to such food.

Access to food is conceived as both physical and economic. While physical access relates more to the distribution of food through the transport infrastructure system, the economic perspective focuses on the purchasing power of people, thus on their ability to afford the food they need. Access can also be considered from a social perspective. For instance, a potential consumer may be precluded to buy and eat the available food in reason of his/her gender or his/her belonging to a particular social group (Napoli et al., 2011, p. 20).

The third dimension, *utilization*, which lies in the words "safe and nutritious food", refers to the need for "adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being" (FAO, 2006, p.1). It also includes other elements, such as the crucial importance of consumer consciousness in selecting, preparing, and storing food (Napoli et al., 2011, p.20). Furthermore, the inclusion of "food preferences" in the definition – in place of "enough food" – is an attempt to incorporate the social and cultural acceptability of food (Pinstrup-Andersen, 2009).

Stability ultimately adds a time dimension to the definition through the words "at all times". It implies that multiple factors, either sudden or cyclical – from economic shocks and conflicts to diseases and natural disasters – could constitute a threat to any of the other three dimensions, and eventually impact the overall food security status of both individuals and communities.

1.2 Including the concept of nutrition security

The conceptualization of food security is constantly evolving – as evidenced by the development of several definitions over the last fifty years – and more recently there has been a call for greater integration with the notion of *nutrition security*. The emphasis on nutrition was already embodied in the most accredited definition of food security formulated during the 1996 World Food Summit – reported above – and more particularly with the recognition of the *utilization* dimension. However, despite the interrelationship between nutrition security and food security has long been recognized, the combination of the two terms proved more ambiguous. The UN Committee on World Food Security (FAO, 2012) reported how the terminology related to the two concepts has evolved throughout the years and summarized the most recent efforts made to combine them in a unique expression. The first attempt to put the two terms *food security* and *nutrition security* together was made with the expression "food security and nutrition", commonly used by the Committee on World Food Security itself from 2009 onwards. With this terminology, the emphasis is on the traditional dimensions of food security and, in addition, the relevance of nutrition is recognized, implying that food security is the necessary condition to achieve nutrition targets, but the two are still considered as complementary, rather than integrated (FAO, 2012). To date, the greatest effort in formulating a comprehensive expression can be identified in the words “food and nutrition security”, a condition that exists “when all people at all times have physical, social and economic access to food, which is safe and consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life” (FAO, 2012, p. 8). “Food and nutrition security” is meant to place emphasis on the existence of a single and overall goal and on the need for policies, actions, research, and programmes jointly aimed at contributing towards its accomplishment (FAO, 2012).

Regardless of the definitions used, what is widely agreed is that health problems related to inadequate nutrition pose a real threat to food security. The UN Sustainable Development Goals (SDGs), in particular the SDG 2.2 (United Nations, 2015), set the objective of ending all forms of malnutrition by 2030, where malnutrition refers to “deficiencies, excesses, or imbalances in a person’s intake of energy and/or nutrients” (World Health Organization, 2020a). The literature on the topic, as well as food policymakers, pay particular attention to the so-called double burden of malnutrition. This is defined as “the coexistence of undernutrition (i.e., micronutrient deficiencies, underweight, and childhood stunting and wasting) and overweight, obesity, and diet-related noncommunicable diseases” (Popkin et al., 2020, p.65), and is a phenomenon currently faced by many low-income and middle-income countries. The fight against malnutrition, in all its forms, is far from being won, as FAO et al. (2020) point out. Indeed, globally in 2019 the number of children under the age of 5 affected by stunting[2] – although lower than the 155 million registered in 2016 (World Health Organization, 2020a) – was still at very high levels, equivalent to 144 million (FAO et al., 2020), corresponding to the 21.3% of children younger than five years old. Undernutrition in children is of particular concern because it severely affects their physical and cognitive development, and also makes them more vulnerable to death and disease (World Health Organization, 2020a). At the same time, the rate of both children and adults affected by overweight is on the rise. The prevalence of overweight children under the age of five amounted to 5.6% in 2019 (FAO et al., 2020) – while it was equal to 5.3% in 2012 – and in 2016 adult obesity rate reached 13.1% – whilst it was 11.2% in 2012 (FAO et al., 2020).

Popkin et al. (2020) have recently pointed out that the double burden of malnutrition – which can be detected at the country, household, but also individual level – is particularly common in Sub-Saharan

[2] Stunting is described as “low height-for-age, reflecting a past episode or episodes of sustained undernutrition. In children under five years of age, stunting is defined height-for-age less than -2 standard deviations below the WHO Child Growth Standards median” (FAO et al., 2020, p.256).

Africa, Southeast Asia, and the Pacific. Moreover, maybe the most interesting finding of their research is that, among low- and middle- income countries (LMICs), severe levels of the phenomenon under consideration have shifted from the richest (in GDP per capita terms) LMICs in the 1990s, to the poorest LMICs at present (Popkin et al., 2020). In fact, although in these countries some advances have been made in the fight against undernutrition, the efforts have proved insufficient to limit the problem. Furthermore, the rapid increase in the prevalence of overweight, driven by changes in the food system and the presence of highly processed food on the market, has exacerbated the malnutrition plague. This evidence is somehow consistent with what in the literature is known as the *nutrition transition*, namely a shift from a diet mainly based on complex carbohydrates and fibres to a more varied one – richer in fats and sugar – once incomes grow and people become more urban (Drewnowski and Popkin, 1997).

1.3 Food safety concerns

Along with the *availability*, *access*, *utilization* and *stability* dimensions, there is another aspect of food security that cannot be overlooked, that is *food safety*. In the words of Ericksen (2008), food safety is actually part of the utilization dimension and relates to the danger of absorbing hazardous substances through food intake. Addressing food safety is therefore extremely important to ensure that food is of acceptable quality and contains the necessary nutrients, i.e., to guarantee food security (Miraglia et al., 2009). Although there is not a universally agreed definition of food safety, it can be said that the issue generally refers to "all those hazards, whether chronic or acute, that may make food injurious to the health of the consumer" (FAO and WHO, 2003, p.3). According to FAO, every year contaminated food (due to viruses, bacteria, parasites, toxins, or chemicals) causes the illness and the death of 600 million and 420,000 people respectively (FAO, 2019a). Guaranteeing that the food supplied – and hence consumed – is safe means safeguarding consumers' health and wellbeing, but also preventing the overburdening of healthcare systems.

Food policies have always taken the aspect of safety into account, but the types of issues to be addressed have changed. Whereas in the past safety concerns stemmed mainly from the risks encountered by field workers in direct contact with pesticides, or the presence of toxins imputable to poor storage, they now relate to pesticide residues in food and biosafety issues more generally (Maxwell and Slater, 2003). According to Lake et al. (2012) the safety of food represents the main concern linked to food in developed nations. Moreover, in line with what Miraglia et al. (2009) pointed out, Lake et al. (2012) emphasize that food safety issues risk being further fuelled by the negative impacts of climate change. In particular, the rise in temperatures – one of the most discussed climatic changes – may facilitate the spread of pathogens and plant pests, and thus necessitate even greater use of pesticides and other chemicals (Miraglia et al., 2009; Lake et al., 2012). In addition, warm and humid climate influences the ability of moulds to produce mycotoxins, substances that are highly dangerous to human and animal health (Miraglia et al., 2009). In this respect, Chakraborty and Newton (2011) focused on the *Fusarium Head Blight* (FHB) fungi case study, and reported that the cereal disease, strongly influenced by weather conditions, was reappearing and damaging crops as well as affecting their quality.

Therefore, in the light of the above, it becomes essential to establish rules to identify and prevent possible food risks to which consumers are exposed. However, the establishment of common parameters that assure the safety of food is a controversial issue since the adoption of standards may vary across countries – due to the adoption of different priorities for example – and consequently impact the international trade of food. For this reason, the adoption of aligned international food standards allows to protect public health, while at the same time to have more efficient trade exchanges (FAO and WTO, 2017). With this purpose, the Codex Alimentarius Commission was born in 1963 from a collaboration between the FAO and the WHO, with the aim of setting international food standards, guidelines, and codes of practice – released as "Codex Alimentarius"[3]– based on scientific evidence.

Furthermore, the World Trade Organization (WTO) acknowledges this set of recommendations in its Sanitary and Phytosanitary (SPS) Measures and Technical Barriers to Trade (TBT) Agreements[4]. They both provide a framework for the adoption of rules aimed at protecting health and ensuring food safety, with particular attention paid to avoiding unjustified frictions in trade (FAO, 2019a; FAO and WTO, 2017). In particular, the SPS Agreement – entered into force in January 1995 – suggests governments to align their national measures to international standards, but nonetheless allows establishing different domestic standards, if they are based on science and aimed at protecting health. In fact, since the mismatch between national requirements and international ones may produce distortions in trade – by protecting domestic actors from foreign competitors – the WTO aims to verify the existence of a scientific rationale behind this divergence, and thus the absence of arbitrary behaviours (FAO and WTO, 2017). What is worthy to note is that the inability to satisfy these requirements constitutes a barrier to access foreign markets for many farmers – especially in

[3] The "Codex Alimentarius" is not legally binding unless countries decide – on a voluntary basis – to incorporate its recommendations in their domestic law (FAO and WTO, 2017).

[4] The SPS Agreement "sets out rules for food safety and requirements for animal and plant health" (FAO and WTO, 2017, p.13), while the TBT Agreement encompasses a wider range of products – not only agricultural – and is aimed at "providing consumer information and ensuring product quality" (FAO and WTO, 2017, p.13).

developing countries – who risk losing their incomes and livelihoods from international trade (FAO and WTO, 2017).

1.4 The complex nature of food systems

Nowadays, even more than in the past, it would be inappropriate and ineffective to limit the analysis of food security to the agricultural sector alone. Since all sectors in the globalised world economy are interconnected, the problem of food insecurity is not reducible to the mere production process, but instead must be tackled with a systematic view, which encompasses the distribution and allocation phase and the proper absorption of food energy by individuals. At this respect, at the dawn of the new millennium Maxwell and Slater (2003) brought to light the huge transformations that were taking place in the global food system and drew attention to the urgent need of a new, more integrated, food policy. In their opinion, such transformations were mainly driven by increased urbanization, rising incomes, as well as by the role of mass media and advertising in modifying consumers' food preferences (Maxwell and Slater, 2003). The idea that an integrated food system approach was needed – capable of capturing the negative social and environmental externalities produced throughout the food value chain – was further developed by Ericksen (2008) some years later, with particular attention paid to the interrelationships with *global environmental change*.

In the view of Ericksen, food systems in their complexity comprehend "the interactions between and within bio geophysical and human environments, which determine a set of activities; the activities themselves (from production through to consumption); the outcomes of the activities (contributions to food security, environmental security, and social welfare) and other determinants of food security" (Ericksen, 2008, pp.234-235). In particular, the interconnection between the natural environment and food security is very deep and complex. The activities of food systems produce negative externalities on the environment and the latter, in turn, influences the activities of food systems, sometimes making it difficult to carry out food production activities. Nevertheless, with reference to the impact of environmental hazards on food security, it is crucial to think about food systems as a whole, because the occurrence of a natural event may not affect food production and yields, but instead could threaten distribution channels on which some communities depend for food (Ericksen et al., 2010).

The cross-cutting nature of modern food systems (Ericksen et al., 2010) makes their good governance difficult, where food security governance is "the formal and informal interactions across scales between public and/or private entities ultimately aiming at the realization of food availability, food access, and food utilization, and their stability over time" (Candel, 2014, p.598). The coordination of food policies, and hence the implementation of an effective food security governance, is not an easy matter. In fact, there are multiple perceptions of the food security problem, and moreover different needs exist, which necessitate context-specific solutions, but also multi-level governments coordination. This raises the question of who decides the policies to be implemented – such as whether public intervention and barriers to trade are appropriate or not for instance – and also who, in the nutritional and qualitative domain, sets the food standards (HLPE, 2020; Candel, 2014; Gibson, 2012).

1.5 The need for a transition to sustainability

With regard to the linkage between *sustainability* and the notion of *food security*, some argue that the former should be seen as the long-term equivalent of the stability dimension, whereas others claim that it should represent an additional, independent, dimension (Berry et al., 2015). In support of the latter vision, the HLPE on Food Security and Nutrition has been proposing for some years a change in the conceptualization of food security through the introduction of two additional dimensions, namely *sustainability* and *agency*[5]. In fact, sustainability is becoming increasingly essential as long as climate change and environmental degradation, together with increasing socio-economic inequalities, deepen across the globe (HLPE, 2020), it being understood that addressing the two issues implies dealing with trade-offs (Berry et al., 2015).

Nowadays food systems are increasingly required to follow the sustainability path in order to prevent undesired impacts on future generations. In fact, it is widely claimed that food systems have to be sustainable, meaning that they should "deliver food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised" (FAO, 2018, p.1). In fact, *sustainability* – which has its roots in the concept of sustainable development[6] – must be pursued across the economic, social, and environmental spheres. An overall balance should be attained by shaping sustainable food systems which embrace inclusive growth, eco-social progress, and green growth (FAO, 2018). Therefore, *sustainable food systems* should be profitable for all the actors involved across the whole food supply chain, promote social progress, and have a positive or, at most, neutral impact on the surrounding natural environment (FAO, 2018). Creating sustainable food systems requires going beyond mere agricultural issues (El Bilali et al., 2019) and having a comprehensive understanding of food systems, which arise from the convergence of natural, institutional, and social systems (Hubeau et al., 2017).

[5] Agency, together with sustainability, is recognized as a key aspect of food security in addition to the four traditional dimensions and involves the "capacity of individuals or groups to make their own decisions about what foods they eat, what foods they produce, how that food is produced, processed and distributed within food systems, and their ability to engage in processes that shape food system policies and governance." (HLPE, 2020, p.8).

[6] In 1987 the Brundtland Commission defined sustainable development as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987, p.41).

Sustainability is considered as the *sine qua non* of both long-term food security and nutrition security, but, in turn, food deprivation negatively impacts social and economic development, crucial elements in the implementation of the sustainability transition (Berry et al., 2015). To realize such transition, Garnett (2014) illustrated three possible directions to be taken: focus on supply-side efficiency; contraction of demand and the abandoning of unsustainable consumption patterns; transformation of the food system. While the first perspective recalls the concept of *sustainable intensification*[7], and the second one that of *sustainable diets*[8], the food system transformation places emphasis on the interconnections among all the activities taking place in the system – from production to consumption – and on the existing imbalances of power within it, also claiming the need of a structural change (El Bilali et al., 2019; Garnett, 2014).

1.5.1 Sustainable Development Goals (SDGs) and food security

The adoption of a food system approach, which incorporates sustainability considerations, is embedded in the United Nations' Sustainable Development Goals (SDGs) set out in 2015 within the Agenda 2030 for Sustainable Development. In particular, the SDG 2 – "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" (United Nations, 2015) – concerns the food security issue and implies the need to deal with it as part of a multidimensional challenge, which encompasses climate-related hazards and natural disasters, poverty, and general health conditions.

Even though the SDGs to be reached by 2030 represent clear and well-shared targets integrated in the sustainability strategy, in practice the guidelines to be implemented are more problematic, since the seventeen objectives, together with several synergies, have also some trade-offs. In particular, as Pérez-Escamilla (2017) points out, a correlation between food security and the set of SDGs can be detected beyond the explicit and direct aims of SDG 2. For instance, ending poverty (SDG 1), promoting good health and well-being (SDG 3), guaranteeing higher education levels for all (SDG 4), empowering women (SDG 5), guaranteeing water and sanitation services (SDG 6), reducing inequalities (SDG 10), and promoting sustainable production and consumption patterns (SDG 12), would altogether create synergies to achieve SDG 2 (United Nations, 2015; El Bilali et al., 2019).

[7] Sustainable intensification refers to agricultural production practices that increase productivity while reducing negative environmental impacts (El Bilali et al., 2019, pp.8-9).

[8] Sustainable diets are defined by FAO as "those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources". http://www.fao.org/nutrition/education/food-dietary-guidelines/background/sustainable-dietary-guidelines/en. Accessed February 2021.

By contrast, SDG 2.3 target – which calls for the duplication of agricultural productivity by 2030 (United Nations, 2015) – collides with other goals, such as those referring to the sustainable use and management of water resources (SDG 6), as well as of marine and terrestrial ecosystems (SDGs 14 and 15), the fight against climate change (SDG 13), and the secure access to affordable, reliable and sustainable energy (SDG 7) (United Nations, 2015; El Bilali et al., 2019). The huge challenges ahead – from the food-energy security trade-off to the threats to rural livelihoods – require the implementation of effective governance tools at all levels (HLPE, 2020).

1.5.2 The European Green Deal and the 'Farm to fork' strategy

In December 2019 the European Commission (2019) presented its new growth strategy – the European Green Deal – based on the urgent need for all sectors to transition towards sustainability, with a view to achieving carbon neutrality[9] on the continent by 2050. This ambitious action plan aims to address the new challenges posed by the natural environment through more efficient use and management of resources, reduction of emissions, and concrete measures to support all those who will suffer most from the green transition, especially by employing the 'Just Transition Mechanism'[10] in an effort to turn challenges into opportunities.

Considering the strong impact that the agri-food chain has on the environment (European Commission, 2020) – contributing to soil, water, and air pollution, and producing harmful effects on biodiversity – a targeted strategy for the European food system was presented in May 2020 as part of the European Green Deal. It is known as 'Farm to Fork' and has the specific aim of making the European food system sustainable. Implementing such a strategy requires that the food system has a positive or at least neutral environmental impact, has capacity to mitigate and adapt to ongoing climate change, provides accessible food that is safe and nutritious for consumers, and guarantees fair compensation for supply chain actors, particularly for farmers (European Commission, 2020). In this context, specific objectives have been set (European Commission, 2020), namely: 50% reduction in the use of chemical pesticides by 2030; at least 50% reduction in nutrient losses (without compromising soil fertility) and at least 20% reduction in the use of fertilizers by 2030; 50% reduction in the sale of antimicrobials for farmed animals and aquaculture by 2030; at least 25% of European agricultural land under organic farming by 2030. In addition, to achieving these objectives, the strategy (European Commission, 2020) is committed to: providing advisory services for primary

[9] As the European Parliament points out, carbon neutrality "means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks", see https://www.europarl.europa.eu/news/en/headlines/priorities/climate-change/20190926STO62270/what-is-carbon-neutrality-and-how-can-it-be-achieved-by-2050, accessed December 2020.

[10] For more information see https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/just-transition-mechanism_en, accessed December 2020.

producers dealing with transition; supporting research and innovation in the field of food and food-related activities; combating food loss and waste; making consumers more informed and aware of their food purchasing choices, so that these are guided by health and sustainability considerations (through a ‘front-of-pack nutrition labelling’ harmonized system, for instance). Furthermore, the ‘Farm to Fork’ strategy considers the possible use of fiscal instruments to reflect in the final price the real environmental costs associated with a food product.

To conclude, the importance of following sustainable diets is well captured in Berry et al. (2015, p.2301)’s words “not all food-secure diets are sustainable, but all sustainable diets are food-secure”.

1.6 The role of trade and contrasting views on food self-sufficiency

The exchange of agricultural products on international markets has been shown to have improved food and nutrition security conditions in many areas. In particular, Brooks and Matthews (2015) affirmed that, on balance, trade openness contributes to enhance each food security dimension, by allowing the movement of food products from surplus to deficit areas (availability), by rising people’s incomes and fostering economic growth (access), and also by providing a choice of diversified diets (utilization). However, despite the importance of international trade in food products is believed to strengthen even more in the future – mainly to offset production failures caused by climate-change-induced events – the negative effects brought by the openness of trade are also widely recognized, notably from the 2007 dramatic increase in food commodities prices (Brooks and Matthews, 2015). In fact, heavy dependence on food imports to satisfy domestic demand constitutes a factor of risk, both because trade flows could be interrupted for any reason, and because the transmission mechanism of international prices onto domestic prices is rapid, which is deleterious in times of soared international food prices (Brooks and Matthews, 2015).

The global trade of food commodities allows net food importers countries – whose insufficient production would result in high prices – to have lower food prices, and net exporting countries – whose production surpluses, if not sold abroad, would make domestic prices tumble – to support prices on the domestic market (Brooks and Matthews, 2015). However, concurrently with the outbreak of the 2007-2008 food crisis, the interest in improving food self-sufficiency levels has re-emerged. Food self-sufficiency, which relates to a country’s ability to satisfy consumption within its national borders with domestic production, should not be regarded as complete closure to international trade with the aim of growing domestically all the food consumed, but more broadly as the capacity of countries to produce food (Clapp, 2017).

In the 1960s and 1970s the food policies designed to pursue self-sufficiency were largely adopted and accepted both in developed and developing countries, but with the advancing of trade liberalization in the 1980s, food self-sufficiency ambitions were explicitly abandoned by the majority of countries, some of which became net food importers (Clapp, 2017). Advocates of the liberalization of agri-food trade promoted their ideas in the name of the pursuit of economic efficiency based on the principle of comparative advantage as a development strategy (Baer-Nawrocka and Sadowski, 2019). In this regard, Clapp (2017) summarized four types of risk associated with food self-sufficiency policies by its leading critics: disruption in domestic food supplies due to a higher risk of production shortages; food prices growth boosted by market distortions; harmful impacts on incomes of poorer farmers who have been denied the possibility to export their products; food production potential limited by environmental conditions. With regard to the latter risk factor, in effect Baer-Nawrocka and Sadowski (2019) found in their study that the natural environment plays a key role in the ability of countries to produce food autonomously, but that, nevertheless, any production gaps can be made up by favourable economic conditions that make the import of foodstuffs possible.

What both Baer-Nawrocka and Sadowski (2019) and Clapp (2017) emphasize is the importance of recognizing that food self-sufficiency policies are not aimed at achieving autarky, but instead at ensuring the level of market protection that, depending on the context analysed, guarantees the best outcomes in terms of food security and country stability. In this regard, Clapp (2017) stated that policies of food self-sufficiency could prove particularly beneficial for: the most food insecure countries which are heavily exposed to external food price volatility; countries whose wealth is very unstable because almost entirely dependent on commodity exports; net food importers countries that do not fully exploit the productive potential of their natural endowments; highly populated countries whose demand can cause significant price fluctuations; countries that rely on few suppliers for their food imports.

To conclude this overview of the food self-sufficiency debate, it is worth mentioning another concept under discussion in the field of agri-food policies – very close to that of food self-sufficiency – that is food sovereignty. The principles underlying the concept of food sovereignty, which was introduced by the international peasant movement *La Via Campesina* in the 1990s, are basically founded on the defence of farmers' rights, the support of domestic and local agricultural production (regardless of comparative advantages), the need to reorganise agricultural trade, and also on the crucial role of small-scale organic farming (Clapp, 2014; Clapp, 2017; Baer-Nawrocka and Sadowski, 2019).

1.7 Public policies in agriculture and the WTO AoA

Public intervention in the economy has always been a matter of debate and, consequently, so has the role of the state in the agricultural sector. Following the Great Depression period, the role of public intervention in countries' development strategies was favourably accepted until the 1980s, from which there was a push for greater liberalisation, imposed particularly on developing countries through Structural Adjustment Programmes (SAPs) promoted by the International Monetary Fund and the World Bank (Chang, 2009). This pressure for change obviously impacted the agricultural policies of many countries, especially developing countries, and laid the groundwork for the entry into force of the 1995 WTO Agreement on Agriculture (AoA). In fact, the main objectives of the AoA are to reform agricultural trade by limiting all kinds of export subsidies and import tariffs – thus leaving room for the free market – and to encourage the implementation of more market-oriented policies (Cardwell and Smith, 2013). The rules and commitments of the AoA are based on three pillars, namely domestic support, market access, and export competition (Hawkes and Plahe, 2013).

On the first pillar, the rules established by the Agreement are normally classified into three 'coloured' boxes, i.e., amber, blue, and green. The *green* box encompasses all domestic support measures that do not directly distort trade or production, and are therefore not subject to limitations, such as funding for research, education, and extension services[11] (Cardwell and Smith, 2013; Hawkes and Plahe, 2013). It is worth noting that the European Union has progressively changed the nature of its support under its Common Agricultural Policy (CAP[12]) and has phased out *blue* box support measures in favour of the *green* box, which now includes 'Single Farm Payments', a decoupled income integration (Cardwell and Smith, 2013) – not linked to production levels – subject to cross-compliance conditions[13].

With regard to the second pillar of the AoA, i.e., market access, a process of 'tariffication' has been put in place to convert non-tariffs barriers, such as quotas, and create a more homogeneous system based only on the application of tariffs as a restrictive measure (Hawkes and Plahe, 2013).

The last pillar on which the AoA is based concerns export competition and, in particular, the need to cut export subsidies, which distort competitiveness by diverting prices away from natural market supply and demand mechanisms. Measures to encourage exports could be taken, for example, to sell domestic surpluses abroad, but the resulting increase in the quantity of agricultural products on international markets could cause international prices to fall. This could create a disadvantageous competition for farmers in other countries, who may be unable to compete with low prices in their own local markets. As part of the general aim of reducing barriers to trade, the AoA therefore

[11] According to Chang (2009, p.491), extension services in agriculture include all forms of technical support that are provided in the first phase of implementation of a new technology.

[12] Since 1962 the CAP is the agricultural policy of the EU; it is founded on the basic principles of market unity, community preference and financial solidarity.

[13] Farmers who want to receive EU income support must comply with several conditions established to: protect animal and plant health; guarantee consumers' health through the supply of "safe" food; encourage the implementation of good and environmentally friendly agricultural practices. See https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/cross-compliance_en, accessed December 2020.

provided for levels of reductions in these instruments, imposed in a differentiated manner depending on the country, more substantial for developed countries, more contained for developing countries (Cardwell and Smith, 2013).

CHAPTER II.

THE INTERCONNECTION BETWEEN FOOD SECURITY AND ENVIRONMENT

The first chapter has presented a broad overview of the literature on food security, emphasizing, among other things, the increasing complexity of modern food systems and their interconnection with the environment. This chapter aims to provide some insights into such interconnectedness from an aggregate perspective. On the one hand, the environmental impact of food systems activities will be explored and, on the other, the main environmental pressures on food production will be illustrated. Furthermore, considering that the primary objective of this research is to analyze the vulnerability of developing countries to food insecurity and to risks posed by the natural environment, this chapter will also shed light on the concept of vulnerability to environmental risk. Finally, mention will be made of the World Food Programme, because of the crucial role it plays in areas where food insecurity is widespread, and vulnerability to factors of instability is high.

2.1 The environmental impact of food systems

Current food production and distribution systems, as well as food consumption patterns, contribute to exacerbating the environmental crisis which, through the occurrence of natural disasters and the adverse effects induced by climate change, seriously threatens food security. The following lines will introduce the main channels through which food systems, as a whole, raise environmental issues.

2.1.1 Threat to forests and biodiversity

It is estimated that 50% of the habitable land (land surface not covered by glaciers or other infertile lands such as deserts) is devoted to agriculture, while 37% is taken up by forests (FAO et al., 2020; Driscoll, 2019). While agricultural areas are undergoing an expansion process, the opposite is true for forest areas, which are heavily affected by the phenomenon of deforestation, of which agriculture is estimated to be the main driver (FAO and UNEP, 2020). In this regard, it was recently estimated by Dow Goldman et al. (2020) that over the period 2001-2015 seven commodities alone (cattle, oil palm, soy, cocoa, coffee, wood fiber, rubber) drove 58% of agricultural-related deforestation expressed in millions of hectares. In particular, during the period analyzed, these commodities occupied 71.9 million hectares of land that used to be forest, the largest share of which devoted to cattle grazing (45.1 Mha) (Dow Goldman et al., 2020). The loss of such natural wealth is particularly worrying given that trees are natural 'carbon sinks'. They are players in the carbon sequestration process described by the United Nations Convention to Combat Desertification (UNCCD, n.d., p. 1) as "the process by which CO_2 sinks (both natural and artificial) remove carbon dioxide from the atmosphere, primarily as plant organic matter in soils". Therefore, the removal of trees, or more generally their loss, coincides on the one hand with a reduced capacity to absorb CO_2, and on the other with the release of previously stored carbon into the atmosphere.

At the same time, deforestation and the conversion of land to agricultural activities are associated with significant losses of biodiversity, which is fundamental to the functioning of ecosystem services (Delzeit et al., 2017). A study carried out by Delzeit et al. (2017) found that there is a strong correlation between areas of potential agricultural expansion and areas rich in mammals, birds and amphibians' biodiversity.

2.1.2 Polluting and resource-intensive activities

The activities carried out by food systems produce negative environmental externalities at every stage, from production to consumption. It is estimated that in the period 2007-2016 the food system as a whole – including crop and livestock activities, land use and land use change, supply chain activities, as well as food losses and waste – contributed between 21 and 37% of greenhouse gas emissions (IPCC, 2019). In particular, agriculture is a major emitter of methane and nitrous oxide – two greenhouses gases – the former being released in large quantities by certain crops grown on a large scale, such as rice, but especially by livestock farming, while the latter is associated with the use of nitrogen fertilizers (Pérez-Escamilla, 2017). The use of fertilizers in agriculture has increased by 800% compared to 1961 levels (IPCC, 2019), and is expected to increase further in the future to boost food production. It is associated not only with air pollution, but also with water pollution, giving rise to the phenomenon of eutrophication, which alters aquatic ecosystems through excessive nutrient influx (Islam and Wong, 2017). Furthermore, in a world where water will become increasingly scarce, agriculture-related activities are particularly threatened considering that they are extremely water-intensive, demanding around 68% of global freshwater withdrawals (Walker et al., 2019).
It is striking to note that food losses and food waste currently accounts for a significant share of total food production, estimated at between 25 and 30% (IPCC, 2019), which is not only a huge paradox considering that millions of people do not have enough food to eat, but above all an inestimable waste of resources. It is generally reported that food waste occurs mainly in developed countries due to consumer behaviour, while food losses – due to production inefficiencies, or to difficulties in storage and preservation during distribution – are mostly found in low-income countries (Pérez-Escamilla,

2017). Also, the burden of food packaging should not be overlooked, much of which is made of plastic that is frequently dumped in marine waters (Driscoll, 2019).

2.1.3 Unsustainable diets

Current dietary patterns are increasingly being labelled as unsustainable, mainly due to the fact that in recent decades, as a result of rising incomes and increasing urbanization, the production and consumption of food of animal origin has soared (Islam and Wong, 2017). The production of meat and dairy products, coupled with the production of animal feed, is associated with a huge exploitation of natural resources, as well as with a major environmental impact. FAO et al. (2020) have estimated that 77% of the environmental impact of today's diets – measured in terms of greenhouse gas emissions – is driven by the consumption of products of animal origin.

While agricultural land used for livestock production – including grazing land and animal feed cropland – accounts for 77% of the total (FAO et al., 2020, p. 105), the output produced for human consumption is much more modest, amounting to 18% and 37% of the caloric and protein supply respectively (Ritchie and Roser, 2020). In addition, meat production is also extremely water-intensive. In this regard, Mekonnen and Hoekstra (2012) carried out a research project on data covering the period 1996-2005 to estimate the impact of the entire livestock sector (meat and animal-derived products) on water consumption levels, known as the *water footprint*[14]. Based on the assumption that the *water footprint* of animals results directly from the water they drink, as well as the water used in related services, and indirectly from the water consumed to provide them with feed, the two authors found that it varies considerably depending on the amount of feed required and the production system used (grazing, mixed, industrial) (Mekonnen and Hoekstra, 2012). In particular, Mekonnen and Hoekstra (2012) estimated that during the period analyzed (1996-2005), 98% of the water footprint of animal production came from the feed consumed, which, among other things, requires as much as 12% of the water supplied by irrigation systems (Mekonnen and Hoekstra, 2012, p. 408). Finally, they were able to prove that products of animal origin have a higher water footprint than crops and products of plant origin, both in terms of tonnes and kilocalories. Therefore, there is currently a strong and widespread recommendation for a transition to more plant-based diets – associated with a lower environmental impact – although it is also recognized that this cannot be

[14] The water footprint results from the combination of the blue, green and grey water footprints, where "blue water footprint refers to the volume of surface and groundwater consumed (that is evaporated after withdrawal) as a result of the production of the product; the green water footprint refers to the rainwater consumed; the grey water footprint refers to the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards." (Mekonnen and Hoekstra, 2012, p. 402).

applied to contexts where the consumption of animal products is deficient and may represent a valuable source of nutrients (FAO et al., 2020).

2.2 Pressures on food production

Food security is hindered by several factors, which, combined with the projected increase in human population, and considering the effects of climate change and the occurrence of extreme natural events, are expected to make its achievement even more difficult. In this framework, it is therefore crucial to identify the main factors affecting food production, which, although it is well known not to be the only factor at play in ensuring food security, is expected to increase in response to population growth. Land and water are undoubtedly the two main limiting factors from a quantitative point of view – which trigger phenomena such as land and water grabbing – but there are also elements that compromise production in terms of quality.

2.2.1 Population growth

The challenges associated with achieving food security are amplified by estimates of a growing global population in the coming decades, which, rising from the 7.7 billion recorded in 2019, is expected to reach 8.5 billion in 2030, 9.7 billion in 2050 and 10.8 billion in 2100 (UNDESA, 2019b). Growth will be driven mainly by countries in Sub-Saharan Africa, a region that is currently the third most populous in the world (after Eastern and South-Eastern Asia, and Central and Southern Asia), which will double its population by 2050 and is estimated to become the most populous by 2100 with 3.7 billion inhabitants (UNDESA, 2019b). Achieving food security then becomes increasingly difficult, since the populations of the poorest countries – which are already unable to meet their basic needs, or do so with difficulty, and are also the most threatened by environmental hazards and extreme climate events – will be the main ones to grow. In particular, it is estimated that the countries whose population will grow the most (in billions) are India, Nigeria, Pakistan, the Democratic Republic of the Congo, Ethiopia, United Republic of Tanzania, Indonesia, and Egypt (UNDESA, 2019b).

2.2.2 Land constraints

The impact that climate change is having, and may have in the future, on the natural environment and on activities necessary for human survival – such as those carried out by food systems – is a matter of major interest. *Climate change* is defined by the Intergovernmental Panel on Climate Change (IPCC) as “the change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity" (IPCC, 2007, p.30). With respect to land and soils, climate change affects the composition of the soil through higher CO_2 atmospheric concentration, higher temperatures, more intensive rainfalls, and occurrence of extreme events. More in detail, it contributes to the depletion of important soil nutrients and the loss of soil fertility, both of which endanger agricultural production and, more generally, it makes land more vulnerable to desertification, degradation, and erosion (Islam and Wong, 2017). Chakraborty and Newton (2011) pointed out that urbanization, conversion of crops to purposes other than food production, and land degradation have the potential to reduce arable land in the coming decades. Accordingly, food production is expected to pursue the path of intensification in the years to come, and this, as in the past, will require the massive use of fertilizers, pesticides, and the adoption of more extensive and robust irrigation systems (Gregory et al., 2005).

2.2.3 Water scarcity

Water scarcity is a limiting factor for crop productivity that is expected to become more acute in the future. In fact, water scarcity will affect more and more regions across the globe and competition for water between sectors will further increase (Fereres et al., 2011).

Focusing on the Middle East and North Africa (MENA) water-scarce region, Antonelli and Tamea (2015) investigated the importance of 'virtual water' (i.e., embedded in agricultural commodities) trade for achieving food and water security in the region, which would otherwise be unable to secure it with its own natural resources. For the purposes of their analysis, the two authors distinguished between *blue* and *green* water: the former includes groundwater and water flowing on the surface, the latter comes from precipitation. Antonelli and Tamea (2015) emphasize the importance of this distinction for the levels of competitiveness among water claimants. In fact, while green water is hardly exploitable by sectors other than agriculture, blue water has more potential users and, consequently, a higher opportunity cost (Antonelli and Tamea, 2015). While green water underpins rain-fed agriculture, blue water is fundamental to irrigation systems. The 72% of global agricultural lands is devoted to rain-fed agriculture (Walker et al., 2019), which is, however, an unstable source of livelihood for farmers as it is highly dependent on variable rainfall patterns (Fereres et al., 2011). The seasonal variability[15] in precipitations is expected to increase in the future due to climate change-induced effects, with the share of cropland subject to extremely high seasonal variability expected to quadruple by 2040 (Walker et al., 2019) and disproportionately affecting the poorest areas, such as those in sub-Saharan Africa, where precipitations are likely to decrease. Furthermore, the impact that

[15] Seasonal variability is "the average within-year variability of available water supply. (…) higher values indicate wider variations of available supply within a year" (Walker et al., 2019).

altered seasons, reduced rainfall, and prolonged periods of drought are expected to have on crop systems may lead to changes in the varieties grown in some locations (Miraglia et al., 2009), but may also affect the production of crops that require specific environmental conditions, such as rice (Islam and Wong, 2017).

However, the unsustainable exploitation of water resources (i.e., *blue* water) by irrigation systems poses problems that are as threatening as those faced by rain-fed agriculture. Indeed, one third of irrigated crops is currently classified under "extremely high water stress"[16] (Walker et al., 2019) and wheat – the most demanded commodity in household consumption – is the one with the highest percentage of crop area exposed to water stress risk (currently higher than 50%, by 2040 it is expected to reach 75%).

2.2.4 Impacts on food safety

Alongside the challenges that food production will face in terms of quantity – although the impact will be heterogeneous across regions, in the sense that some areas will be able to benefit from temperatures suitable for cultivation – there are growing concerns about the possible consequences for food quality. In particular, Miraglia et al. (2009) brought to light the issue of the impact that various climate changes may have on food safety by altering the spread of pathogens and producing effects on animal and plant diseases. In fact, it has been estimated that higher temperatures and more frequent extreme events can favour the emergence of new pests and alter their transmission – thus changing pathogens-vectors-hosts patterns – with greater repercussions on plants, but also on animals (Miraglia et al., 2009). In addition, Chakraborty and Newton (2011) pointed out that the vulnerability of crops to insect and pest attacks is higher, compared to wild plants, due to the changes that their natural development has undergone in order to increase yields. These new risks will therefore require massive use of agrochemicals, but also of animal antibiotics, both of which raise human health concerns. In the first case, these harmful substances can be assimilated through the consumption of food, while in the second the overuse of medicines can increase antibiotic resistance in animals and, consequently, in humans (Miraglia et al., 2009; Lake et al., 2012). Lastly, it should not be overlooked that toxic substances produced by moulds (in terrestrial ecosystems) and algae (in marine ecosystems) – harmful to crops and to seafood respectively – are expected to find even more favourable environmental conditions to flourish (Miraglia et al., 2009).

[16] According to the World Resources Institute, "extremely high water stress" means that over 80% of surface and groundwater supplies is withdrawn, on average, every year (Walker et al., 2019).

2.3 Understanding vulnerability to environmental risks

In the context of the interconnection between food systems activities and the natural environment – about which this chapter has so far provided some insights – attention is given to the link between risks posed by the natural environment and food insecurity. It is therefore essential to identify the factors that determine vulnerability to environmental risks, firstly to have criteria for identifying the most vulnerable areas, but also to understand where it is most effective to act to better deal with risks. The IPCC (2007, p. 64) states that "vulnerability to climate change is a function of exposure, sensitivity and adaptive capacity". In this framework, and with a view to sustainable development, the adoption of mitigation and adaptation measures plays a key role, with the former aiming to reduce exposure, and the latter to reduce sensitivity (IPCC, 2007).

In the field of disaster risk management (i.e., the one that designs strategies aimed at preventing and minimising disasters risks), an important step has been taken at international level with the agreement reached by UN member countries in 2015, that led to the adoption of the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015). The Sendai Framework, which applies to all kinds of disasters – both man-made and natural – aims to achieve "the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries" (UNDRR, 2015, p. 11). Actions for disaster risk reduction should fall into four areas: the full understanding of disaster risk; an effective disaster risk governance at all levels; investments to improve disaster resilience; the preparation of effective disaster response measures (UNDRR, 2015, p. 13).

2.4 The World Food Programme: a key actor

The World Food Programme (WFP) is a UN agency established in 1961 with the aim of combating hunger and providing support to food insecure people living in vulnerable areas and in emergency conditions. It is therefore a major actor in the field of food security, especially in view of the *Zero Hunger* goal set by the 2030 Agenda. The range of activities carried out by the WFP – in collaboration with governments, private actors, Non-Governmental Organizations (NGOs), local stakeholders, institutional actors and other UN agencies – is varied and adapted to the different contexts in which it operates, as a result of location-specific analysis and planning. It combines long-standing and well-established support in the form of food aid – where food is not available – and humanitarian support – in conflict and emergency situations – with interventions aimed at improving the resilience of the most vulnerable communities against shocks of various kinds, with a view to structurally addressing the causes of food and nutrition insecurity in the long term. In 2019, 97 million people in 88 countries were recipient of support from the UN agency, of which more than a third was provided in the form of cash assistance, which empowers recipients and has beneficial multiplier effects for local economies (World Food Programme, 2020a).

2.4.1 WFP's commitment in disaster risk management

The WFP is actively involved in climate action, responding to climate-related natural disasters that undermine food security in all its dimensions, but also carrying out preventive activities aimed at reducing risk and vulnerability to shocks. These activities are part of the efforts that the UNDRR (2015) has requested to the international community by calling for support to developing countries that are particularly vulnerable to natural disasters and often lack the capacity to cope with them. In particular, the WFP combines food assistance with asking beneficiaries for socially useful activities, such as rehabilitating assets that help increase resilience to future shocks – degraded land restoration activities for instance – but also by granting insurance schemes against environmental risks (World Food Programme, 2020a). The former strategy falls under the Food assistance For Assets (FFA) scheme, which, while meeting immediate needs for food, aims to safeguard the natural environment. It does so by supporting local communities in the sustainable use of natural resources (land and water above all), the restoration of the natural capital potential, the rehabilitation of transport infrastructures as well as of other services (like storage warehouses, schools), and also the development of skills for effective asset management and response to shocks (World Food Programme, 2019). FFA is therefore intended to be an effective tool to mitigate the risks associated with the occurrence of disasters and to make exposed populations more resilient in the long term. It is estimated that in 2018 the FFA programme benefited 10 million people in 55 countries, rehabilitated 122,500 hectares of land, constructed 3,000 water ponds/shallow wells/fishponds, built or rehabilitated 10,000 kilometers of supply routes, and planted 4,000 hectares of forest (World Food Programme, 2019).

The FFA programme is part of a larger initiative called R4 Rural Resilience Initiative (R4) – a collaboration between the WFP and Oxfam America – which has the primary aim of supporting farmers whose food security and livelihoods are threatened by climate risks. R4 is an integrated risk management strategy that allows farmers to be covered by climate insurance in return for their work in risk reduction activities, such as building infrastructures and improving farming practices (World Food Programme and Oxfam America, 2019). This mechanism offers farmers protection that has a twofold positive effect. On the one hand, the transfer of risk to the insurer encourages farmers to invest in riskier activities and more productive inputs. On the other hand, adverse effects from extreme events, such as crop failure, are cushioned by compensation payments that prevent farmers from selling their assets to recoup their losses (World Food Programme and Oxfam America, 2019).

2.4.2 The 2020 Nobel Peace Prize winner

Many recent WFP operations have taken place in conflict-affected areas, such as Somalia, Yemen, Syria, and South Sudan. Because of such commitments in highly unstable and vulnerable areas, the WFP was awarded the Nobel Peace Prize in 2020 "for its efforts to combat hunger, for its contribution to bettering conditions for peace in conflict-affected areas and for acting as a driving force in efforts to prevent the use of hunger as a weapon of war and conflict" (The Nobel Prize, 2020). The interdependence between conflict and food insecurity was officially recognized with the resolution adopted by the Security Council of the United Nations in 2018. It reminded parties to conflict that any attack on food systems, at any stage, or other means of civilian survival constitutes a crime under international humanitarian law, and furthermore strongly condemned the deprivation of food as a means of warfare (United Nations, 2018). The World Food Programme (2020b) has recently emphasized the impressive figures proving the huge impact that conflict-related instability has on food security. The 60% of the world's hungry live in conflict areas, and conflicts are the main driver of food crises in 8 out of 10 countries, also causing the highest number of outward migrations (World Food Programme, 2020b). Furthermore, the disruptions of food activities in conflict-affected areas have such an impact on food prices that in some cases the daily wage may not be enough to pay for a basic meal (for instance, in South Sudan the 186% of a daily salary would be necessary for a plate of rice and beans) (World Food Programme, 2020b).

CHAPTER III.

FOOD (IN)SECURITY INDICATORS:

AN OVERVIEW ON RECENT DEVELOPMENTS

The fight against food insecurity is fought on several fronts, in line with the multidimensional nature of food security and the complexity of modern food systems. It is important to identify the areas and countries that are considered to be most at risk of food insecurity, as this allows to understand where action measures should be directed and to investigate which factors most influence this state of affairs in these areas. This chapter therefore intends to provide an overview of the countries which, according to the latest available data for selected indicators, are considered to be the most food insecure or most vulnerable to the risk of food insecurity. Moreover, some global and regional trends observed in recent years in the prevalence of undernourishment and the prevalence of moderate or severe food insecurity will be presented, with a view to achieving SDG 2 in 2030. Finally, the impact that the recent Covid-19 pandemic has had on the functioning of food systems as a whole, but above all on the food security of many countries, that were already in a vulnerable situation, will be outlined.

3.1 The main food insecurity hotspots in 2019

The *State of Food Security and Nutrition in the World 2020* report (FAO et al., 2020) states that the world is not on the right track to achieve the targets set by the 2030 Agenda for Sustainable Development (United Nations, 2015). More specifically, the targets set to "ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food for all people all year round" (SDG 2 Target 2.1) and to "end all forms of malnutrition" (SDG 2 Target 2.2) (United Nations, 2015). In fact, the report illustrates that in 2019 the number of undernourished people increased for the fifth year in a row, amounting to nearly 690 million people globally – 60 million more than in 2014 – and that by 2030 this number is projected to exceed 840 million[17] (FAO et al., 2020).

The *Global Report on Food Crisis 2020*, a document produced annually by the Global Network against Food Crises[18], is an informative tool which aims to assess acute food insecurity conditions

[17] This projection does not take into account the impact of the COVID-19 pandemic.

[18] The Global Network against Food Crises is an international alliance of humanitarian and development actors working together to analyse the drivers of food crises across the globe; it was co-founded in 2016 by the European Union, the Food and Agriculture Organization and the World Food Programme.

worldwide and to identify the key drivers in the most affected countries. The report relies on data from 71 countries selected on the basis of their need for humanitarian assistance or external assistance for food. Most governments of the selected countries adopt the Integrated food security Phase Classification[19]/Cadre Harmonisé (IPC/CH) protocol to classify the magnitude of acute food insecurity. According to the IPC, acute food insecurity is "any manifestation of food insecurity at a specific point in time of a severity that threatens lives, livelihoods or both, regardless of the causes, context or duration. These acute states are highly susceptible to change and can manifest in a population within a short amount of time, as a result of sudden changes or shocks that negatively impact on the determinants of food insecurity and malnutrition" (FSIN, 2020, p. 11). Instead, for the few countries not adopting the IPC/CH protocol, the report resorted to other data sources to estimate the state of acute food insecurity (FSIN, 2020).

The IPC/CH identifies five stages of acute food insecurity conditions: 1-none/minimal, 2-stressed, 3-crisis, 4-emergency,5-catastrophe/famine. It does this by combining information from indicators on food consumption levels, changes in livelihoods (strategies and assets), estimates of nutritional status and mortality, with other context-specific contributing factors – such as indicators that can be associated with the four dimensions of food security (i.e., availability, access, utilization, stability) – and estimates of the potential effects of hazards of various kind on food consumption and livelihoods (FSIN, 2020, p. 222).

The first column of Table 3.1 therefore mentions the ten countries that in 2019 had the highest number of people in crisis[20], emergency[21], or catastrophe[22] – i.e., the phases corresponding to the most critical conditions according to the IPC/CH protocol, associated with the need for immediate countermeasures. The ten countries listed account for the 65% of the entire population classified as in crisis or worse by the analysis (FSIN, 2020), and they are all located in Asia and Middle East, Africa, Latin America, and the Caribbean. In particular, based on the number of people experiencing food crises in 2019, Yemen (15.9 million), the Democratic Republic of the Congo (15.6 million), and

[19] As described on the IPC website, the IPC, starting from different methodologies and multilevel collaborations involving different actors, provides a common global scale for assessing the state of food insecurity – both acute and chronic – and malnutrition. See http://www.ipcinfo.org/ipcinfo-website/faqs/en/, accessed December 2020.

[20] According to the IPC/CH, households in Phase 3-Crisis "either have food consumption gaps that are reflected by high or above-usual acute malnutrition; or are marginally able to meet minimum food needs but only by depleting essential livelihood assets or through crisis-coping strategies" (FSIN, 2020, p. 14).

[21] According to the IPC/CH, households in Phase 4-Emergency "either have large food consumption gaps which are reflected in very high acute malnutrition and excess mortality; or are able to mitigate large food consumption gaps but only by employing emergency livelihood strategies and asset liquidation" (FSIN, 2020, p. 14).

[22] According to the IPC/CH, households in Phase 5-Catastrophe/Famine "have an extreme lack of food and/or other basic needs even after full employment of coping strategies. Starvation, death, destitution, and extremely critical acute malnutrition levels are evident. For Famine classification, area needs to have extreme critical levels of acute malnutrition and mortality" (FSIN, 2020, p. 14).

Afghanistan (11.3 million) were ranked as the most affected countries, where conflict was identified as the main aggravating factor in already widespread food insecurity. In fact, Yemen – which has been experiencing the worst humanitarian crisis in the world – has almost 16 million people belonging to the three deepest food insecurity phases, accounting for the 53% of the country's population (FSIN, 2020). In the Democratic Republic of the Congo violent internal conflicts damaged the food production, trade and transport systems, and the Ebola epidemic further aggravated the situation. Conflicts were the main driver of food crises also in South Sudan, the Syrian Arab Republic, and Northern Nigeria. In 2019 in South Sudan there were 7 million people in crisis or worse (IPC/CH phase 3 or above) representing the 61% of the total population in the country; the conflict-related insecurity was discovered to be the main source of the country's food insecurity condition, additionally exacerbated by a prolonged macroeconomic crisis (FSIN, 2020).

Table 3.1. Countries most affected by food crises in 2019

Countries Ranking (from the most affected to the least)	**Crisis or worse* 2019**		**Stressed conditions** 2019**	
	Million people	**% population**	**Million people**	**% population**
1	Yemen (15.9)	South Sudan (61)	Dem. Rep. of the Congo (27)	Venezuela (60)
2	Dem. Rep. of the Congo (15.6)	Yemen (53)	Nigeria (18.8)	Dem. Rep. of the Congo (45)
3	Afghanistan (11.3)	Central African Rep. (41)	Venezuela (17)	Kenya (43)
4	Venezuela (9.3)	Zimbabwe (38)	Sudan (11.8)	Central African Rep. (41)
5	Ethiopia (8)	Afghanistan (37)	Ethiopia (10)	Eswatini (39)
6	South Sudan (7)	Syrian Arab Rep. (36)	Afghanistan (9.5)	Lesotho (38)
7	Syrian Arab Rep. (6.6)	Haiti (35)	Yemen (8.9)	Honduras (35)
8	Sudan (5.9)	Mozambique (34)	Kenya (6)	Namibia (35)
9	Northern Nigeria (5)	Palestine (33)	Malawi (5)	Ethiopia (34)
10	Haiti (3.7)	Venezuela (32)	Guatemala (4.8)	Somalia (34)

* IPC/CH phase 3 or above - in crisis or worse (emergency, catastrophe/famine).
** IPC/CH phase 2 - in stressed conditions.
Source: 2020 Global Report on Food Crises, FSIN (2020).

Instead, economic shocks were the main driver of food crises in Venezuela, Sudan, and Haiti. Venezuela, the richest country in oil reserves in the world[23], has been experiencing a profound

[23] In 2020 the highest value of oil reserves, equal to 302 billion barrels, was registered in Venezuela, followed by Saudi Arabia (267), and Canada (168). See https://www.theglobaleconomy.com/rankings/oil_reserves/, accessed October 2020.

socioeconomic crisis since 2013, when global oil prices started to sharply decline. In fact, the economic recession and hyperinflation, the over-reliance on food imports and food shortages exacerbated food insecurity in the country and forced many people to migrate, especially in Colombia and Ecuador (FSIN, 2020). In both Sudan and Haiti, currency depreciation, high inflation, and livelihood disruptions were the main drivers of the food crisis; also, both countries' agricultural production were challenged by weather extremes and pest infestations. Finally, the main driver of the 2019 Ethiopian food crisis was extreme weather. Some shifts in rainfall patterns created the conditions for the transmission of animal diseases through water, but also for damage to crop production, with major repercussions on cereal prices in the country (FSIN, 2020).

In addition to the values of the population in crisis or worse in million people, it is of more interest to look at which countries have recorded the highest percentages of individuals falling into this category out of their total populations. In this perspective, in addition to the above-mentioned very high percentages recorded in South Sudan (61%) and Yemen (53%), other countries emerge with percentages of the population belonging to this category greater than 30 per cent. Some of them do not appear among the countries listed in the first column (those with the highest number of people in crisis of worse, in millions) – Central African Republic (41%), Zimbabwe (38%), Mozambique (34%) and Palestine (33%) – while others do, namely Afghanistan (37%), the Syrian Arab Republic (36%), Haiti (35%), and Venezuela (32%).

As can be seen, most of the countries mentioned in the first column of Table 3.1 – all except South Sudan, the Syrian Arab Republic and Haiti – also appear among the ten countries with the highest number of people belonging to the IPC/CH phase 2[24] (Table 3.1, column 3), and namely those living in 'stressed' conditions. People classified under this phase are particularly vulnerable to a higher food insecurity risk, and thus to a deterioration of their position. In addition to the countries which already presented the highest number of people in crisis, emergency, or catastrophe, in this list appear also Kenya, Malawi and Guatemala, with respectively 6, 5, and 4.8 million people. In all the three countries weather extremes were the major driver of the 2019 food crisis, mainly characterized by production shortfalls and a rise in food prices (FSIN, 2020). As previously, it is worth looking at the incidence of the population classified as being in 'stressed' conditions over the total population of the country. From this perspective, Venezuela is by far the country with the highest percentage (60%), followed by the Democratic Republic of the Congo (45%), Kenya (43%), and the Central African Republic (41%). It can be observed that, with the exception of Ethiopia, all the other countries listed (Central African Republic, Eswatini, Lesotho, Honduras, Namibia, Somalia) do not appear among

[24] According to the IPC/CH, households in Phase 2-Stressed "have minimally adequate food consumption but are unable to afford some essential non-food expenditures without engaging in stress-coping strategies" (FSIN, 2020, p.14).

the countries with the highest number of people in ‘stressed’ conditions (Table 3.1, column 3), but nevertheless show high percentages, between 34 and 41%. This confirms the relevance of considering the incidence of the population in ‘stressed’ conditions on the total population of the country.

An attempt to provide an overall measure of vulnerability to food insecurity is also made by the Economist Intelligence Unit (2019). It accounts for the categories of affordability[25], availability[26], quality and safety[27] of food – each of them includes a number of meaningful indicators, which are subsequently normalized, based on the most authoritative data sources (such as FAO, World Bank, WTO, to name a few) – combined into one single index, the Global Food Security Index (GFSI). The range goes from 0 to 100, being the highest value the optimal level of security. The GFSI 2019 relies on data from 113 countries and includes two versions, namely the baseline and the adjusted. The latter is a revised version of the former, differing in that it also takes into account the role that climate variability and natural resource risks may have on food security, and thus on the scoring of the other three categories.

The method adopted by the Economist Intelligence Unit (2019) provides partially different evidence from that found with the IPC framework, shown in Table 3.1. As mentioned above, the latter, on the basis of international standards and the most recent available information specific to each local context – even if partial and coming from different sources – aims at providing a picture of the recent levels of acute insecurity and does so by establishing reference thresholds on which the belonging to the different levels of severity depends. On the other hand, the GFSI – which does not only take into account food aid-dependent countries – aims not just to make the various categories comparable across countries through a process of normalization of all indicators, but also to highlight which categories, and which indicators, are most challenging for food security in each country. For example, the 2019 report (Economist Intelligence Unit, 2019) found that farmers' inability to access financing was one of the indicators most highly correlated with a poor index (undesirable levels of food security), as five of the countries with the lowest overall score (Chad, Democratic Republic of the Congo, Haiti, Syria, and Yemen) recorded zero in this indicator. In addition, this index is intended to give particular emphasis to the category related to exposure and vulnerability to environmental risks, as it allows, through the counting of two separate overall scores – one including the risk category,

[25] Indicators included in this category are change in average food costs, proportion of population under global poverty line, GDP per capita, agricultural import tariffs, presence of food safety-net programmes, access to financing for farmers (Economist Intelligence Unit, 2019).

[26] Indicators included in this category are sufficiency of supply, public expenditure on agricultural research and development, agricultural infrastructure, volatility of agricultural production, political stability risk, corruption, urban absorption capacity, food loss (Economist Intelligence Unit, 2019).

[27] Indicators included in this category are dietary diversity, nutritional standards, micronutrient availability, protein quality, food safety (Economist Intelligence Unit, 2019).

one excluding it – to assess the impact it has on food security.

Looking at the evidences illustrated in Table 3.2, it appears that in 2019, according to the baseline GFSI 2019, the ten most food secure countries were Singapore (87.4), Ireland (84), the United States (83.7), followed by other nations located in the European continent (with the exception of Canada). On the contrary, the lowest scores were registered in Venezuela (31.2), Burundi (34.3), and Yemen (35.6), followed by other African countries (except for Syria). In particular, in Venezuela the food (in)security status depended mainly on the availability and affordability dimensions, in which the country registered scores equal to 32.2 and 15.8, respectively (Economist Intelligence Unit, 2019). More in detail, the null score was assigned to indicators related to the cost of the average basket of food, to the poverty level of the population, to corruption and to the country's ability to cope with urban growth[28]. In Burundi and Yemen all the three categories' scores were of particular concern due to their low levels but, being their affordability scores – 36.6 and 45.5 respectively – still higher than that of Venezuela (15.8), they did not take the first place of the ranking.

Table 3.2. The Global Food Security Index 2019

Countries Ranking	Baseline* 2019 (0-insecure, 100 secure)		Adjusted** 2019 (0-insecure, 100 secure)		Natural Resources and Resilience category 2019 (0-worst score, 100 best score)
	The most secure	The most insecure	The most secure	The most insecure	
1	Singapore (87.4)	Venezuela (31.2)	Ireland (77.9)	Venezuela (28.2)	Bahrain (39)
2	Ireland (84)	Burundi (34.3)	Finland (77.5)	Yemen (30.3)	Yemen (40.4)
3	United States (83.7)	Yemen (35.6)	Switzerland (77.3)	Congo, Dem. Rep. (30.8)	Tajikistan (40.5)
4	Switzerland (83.1)	Congo, Dem. Rep. (35.7)	Sweden (76.9)	Burundi (31.2)	Indonesia (40.7)
5	Finland (82.9)	Chad (36.9)	Norway (76.5)	Chad (32.6)	Singapore (42.4)
6	Norway (82.9)	Madagascar (37.9)	Denmark (75.7)	Syria (33.1)	Philippines (42.5)
7	Sweden (82.7)	Syria (38.4)	United States (75.6)	Madagascar (33.8)	Oman (43.8)
8	Canada (82.4)	Sierra Leone (39)	Austria (75.5)	Sierra Leone (34.1)	United Arab Emirates (43.9)
9	Netherlands (82)	Mozambique (41.4)	Canada (75.3)	Mozambique (36.1)	Benin (44.1)
10	Austria (81.7)	Malawi (42.5)	Netherlands (75.3)	Haiti (38.2)	Dominican Republic (44.2)

* Accounts for: affordability, availability, quality and safety.
** Baseline index adjusted by 'Natural Resources and Resilience' scores.
Source: Global Food Security Index 2019, Economist Intelligence Unit (2019).

[28] The 'urban absorption capacity index' (World Bank, World Development indicators; EIU) evaluates "a country's resources (real GDP) against the stress of urbanization (urban population growth rate). It is calculated as the average (annual) real percentage change in GDP minus the urban population growth rate" (Economist Intelligence Unit, 2019).

The adjustment factor *Natural Resources and Resilience*[29] allows to obtain a modified index able to capture the interconnection between the food system and the environment. As for the three categories included in the baseline index (availability, affordability, quality and safety), the values recorded by countries for each indicator under this category were normalized by the Economist Intelligence Unit (2019) to obtain a common measure ranging from 0 to 100. The highest value corresponds to the most favourable condition to cope with risks posed by the environment. Subsequently, the adjusted index score was obtained combining the baseline index with the *Natural Resources and Resilience* category score and a weighted adjustment coefficient of 25%[30] (Economist Intelligence Unit, 2019).

The above mentioned most and least food secure countries all worsened their scores with the introduction of the new category, however some of them lost more points than others, generating differences in the adjusted final ranking. The ten most food secure countries remained the same as those of the baseline index, except for Singapore, which lost its first place and disappeared from the top of the list. Indeed, Singapore appears among the countries which registered the worst score in the *Natural Resources and Resilience* category (42.4), and this performance seems to impact heavily on the overall score, demonstrating the potentially severe vulnerability of food systems to environment-related factors. In particular, based on the scores obtained in the different indicators incorporated in the additional category, in Singapore the heaviest weaknesses are related to the exposure to sea level rise and weather-related events, but especially to the strong food import dependency. In fact, since Singapore imports the 90% of its food supply, the city-state is particularly sensitive to external shocks that may cause supply chain disruptions (Mok et al., 2020). In order to mitigate the unavoidable risks tied to the limited food production capacity – mainly due to natural resources constraints – the Singapore Food Agency recently adopted a triple strategy. It is based on the diversification of import sources, the support of the local industry to meet the 30% of domestic nutritional needs by 2030, and the encouragement for local companies to invest abroad and meet Singaporean food demand from overseas (Singapore Food Agency, 2020).

By contrast, Denmark entered the top-ten ranking of the most food secure countries (75.7), proving that the introduction of the adjustment factor improved its rank position. Other countries improved their ranks as well – namely Finland, Switzerland, Sweden, Norway, and Austria – especially the Nordic countries are well represented in the upper part of the list.

[29] Indicators included in this category concerns the issues of exposure to the impacts of climate change (temperature rise, flooding, drought, sea level rise); water quantity and quality risks; land degradation; health of oceans; sensitivity to the depletion of natural resources; adaptive capacity; demographic stress (Economist Intelligence Unit, 2019).

[30] The adjusted GFSI score is calculated as follows: X* (1-Z) + (X* (Y/100) *Z), "where X is the original overall score, Y is the Natural Resource and Resilience score, and Z is the adjustment factor weighting. The default setting for the adjustment factor weighting is 0.25 = 25%." (Economist Intelligence Unit, 2019).

On the other hand, the ten most insecure countries confirmed their bad performances, in fact almost all of them worsened or maintained their position. However, a slight change can still be observed, since Haiti (38.2) entered the list displacing Malawi, denoting that for the former country the *Natural Resources and Resilience* category is more challenging compared to the latter. In addition, it is worth emphasizing that Yemen, already in the very first positions of the most food insecure countries, is also particularly vulnerable to the adjustment factor, indeed the country has the second-lowest score in the *Natural Resources and Resilience* category (40.4). More generally, according to what reported in the last column of Table 3.2, Asia and the Middle East is the macro region most affected by unfavourable scores in the risk factor.

3.2 The four dimensions of food security

As outlined in the chapter covering the theoretical framework of food security, the achievement of food security is ensured by the fulfilment of its four dimensions: availability, access, utilization, and stability. In this respect, the FAO (2020a) has in recent years started to provide a set of indicators for each dimension in an effort to give a picture, even if fragmented, of the food security issue in its complexity. Therefore, the tables in this section, based on the most recent values recorded for some of these indicators, show which countries have been most affected by food insecurity in its many facets.

3.2.1 Availability

The *availability* dimension, historically the first to be identified, focuses on food from a quantitative point of view, in other words, the ability of the supply-side to provide sufficient quantities of food. With respect to this dimension, four indicators (average Dietary Energy Supply (DES) adequacy; share of DES derived from cereals, roots, and tubers; average supply of protein of animal origin; average value of food production) have been considered for the ranking of countries, which, based on their scores, provided evidence of insufficient availability. The first column of Table 3.3 shows the ten countries that, according to a three-year average score over the period 2017-2019, recorded the lowest percentage of Dietary Energy Supply (DES) over the Average Dietary Energy Requirement (ADER) estimated for their populations, namely the DES adequacy. This indicator provides a measure of adequacy of food supply in terms of calories (FAO, 2020a). Specifically, the DES is a measure that expresses the availability of food for human consumption in terms of daily kilocalories per capita, "[…] calculated as the food remaining for human use after deduction of all non-food utilizations (i.e., food = production + imports + stock withdrawals − exports − industrial use − animal feed – seed – wastage − additions to stock). Wastage includes loss of usable products occurring along distribution chains from farm gate (or port of import) up to retail level." (FAO et al., 2020, p. 253). The Dietary Energy Supply (DES) is calculated with respect to the Average Dietary Energy Requirement (ADER) calculated for the population of a country, where the dietary energy requirement is "the amount of dietary energy required by an individual to maintain body functions, health and normal activity. […] dependent upon age, sex, body size and level of physical activity" (FAO et al., 2020, p. 253).

Six out of the ten countries with the worst DES adequacy (Table 3.3, column 1) are located in the African continent, more specifically in the Sub-Saharan area – namely Somalia (76), Central African Republic (79), Zimbabwe (84), Madagascar (88), Uganda (90), and Zambia (90) – nevertheless the caloric supply appears inadequate also in countries belonging to Latin America and the Caribbean – Bahamas (82), Haiti (91), and Venezuela (91) – and in the Democratic People's Republic of Korea (83).

Table 3.3. The availability dimension of food security

Countries Ranking	**Average DES 2017-2019 (% ADER)**	**PoU 2017-2019 (% population)**	**DES derived from cereals, roots and tubers 2015-2017 (% DES)**	**Average supply of protein of animal origin 2015-2017 (gr/caput/ day)**	**Average value of food production 2014-2016 (I$/caput)**
1	Somalia (76)	Haiti (48.2)	Madagascar (79)	Ethiopia (5.3)	Macao, China (3)
2	Central African Republic (79)	Dem. People's Rep. of Korea (47.6)	Bangladesh (79)	Nigeria (7)	Hong Kong, China (5)
3	Bahamas (82)	Madagascar (41.7)	Ethiopia (75)	Rwanda (8)	Singapore (5)
4	Dem. People's Rep. of Korea (83)	Chad (39.6)	Afghanistan (74)	Mozambique (8.3)	Maldives (16)
5	Zimbabwe (84)	Liberia (37.5)	Mozambique (72)	Madagascar (9)	Greenland (21)
6	Madagascar (88)	Rwanda (35.6)	Lesotho (71)	Guinea-Bissau (9)	Qatar (25)
7	Uganda (90)	Mozambique (32.6)	Malawi (70)	Togo (9)	Bahrain (30)
8	Zambia (90)	Lesotho (32.6)	Zambia (70)	Haiti (9)	Bermuda (33)
9	Haiti (91)	Venezuela (31.4)	Timor-Leste (70)	Tanzania (9.7)	Equatorial Guinea (36)
10	Venezuela (91)	Timor-Leste (30.9)	Sierra Leone (69)	Liberia (9.7)	Saint Kitts and Nevis (46)

Source: Suite of Food security indicators, FAO (2020a).

It is worthy to compare this indicator with the Prevalence of Undernourishment (PoU) which is by far the indicator for which there is the widest availability of data, both old and recent, for most countries (Berry et al., 2015). Although the PoU does not really fall within the *availability* dimension, such a comparison makes it possible to argue whether the countries that experienced high percentages of people undernourished are also the ones with an inadequate dietary energy supply. In fact, the PoU is "an estimate of the proportion of the population that lacks enough dietary energy for a healthy, active life" (FAO et al., 2020, p. 256). Therefore, comparing the first two columns of Table 3.3 allows to presume that the high percentages of undernourishment observed in Haiti (48.2), the Democratic People's Republic of Korea (47.6), Madagascar (41.7), and Venezuela (31.4) are explicable by a certain level of deficiency in the availability dimension, since these countries are also mentioned among the ten with the lowest level of DES adequacy. It is necessary to specify that Somalia, the Central African Republic, Bahamas, Zimbabwe, Uganda, and Zambia, do not appear in the second column for the sole reason that data were not available to determine their PoU. On the contrary, countries such as Chad, Liberia, Rwanda, Mozambique, Lesotho and Timor-Leste show high PoU, and level of DES adequacy slightly higher than those of the ten countries listed in the first column, equal respectively to 95, 97, 97, 95, 93, 97. However, levels of average DES adequacy below 100 still denote the failure to achieve the dietary energy requirement of the population and this, when combined with the fact that even sufficient availability does not always translate into actual consumption for all, increases the likelihood of widespread undernourishment. Nevertheless, it must be said that the vast majority of the countries analyzed exceeded the percentage of one hundred, meaning that their food supply at aggregate level was more than sufficient to satisfy the average dietary energy requirement.

While, at first, food security was believed to be achievable with the increase of agricultural production alone – and thus with a generalized increase in the supply of food – starting from the second half of the twentieth century the nutritional adequacy of diets gained more and more importance in the food security discourse (FAO et al., 2020). According to the World Health Organization (2020b), a healthy diet is essential to guarantee the assimilation of the micro and macro nutrients[31] that every person needs throughout his or her life to develop properly and to live in a state of physical and mental well-being. A healthy diet requires a balanced, adequate, and diverse selection of food consumed, and it varies depending on individual characteristics and on the cultural and local context considered (World Health Organization, 2020b). Despite this recognized heterogeneity, some universal guidelines are nevertheless provided, and they involve the need to "limit total fat to 30% of total energy intake;

[31] According to WHO, macronutrients are consumed in relatively large quantities and include proteins, carbohydrates, fats, and fatty acids; micronutrients – vitamins and minerals – are consumed in relatively smaller quantities, but are essential to body processes, see https://www.who.int/elena/nutrient/en/, accessed October 2020.

saturated fats less than 10% and trans-fats less than 1% of total energy intake; less than 10% of total energy intake from sugars; consumption of at least 400g of fruits and vegetables per day; limitation of salt intake to a maximum of 5 g per day" (World Health Organization, 2020b). However, the cost of a diet varies according to its quality, indeed it has been estimated that the cost of a *healthy diet* – the one of better quality – is 60 percent higher than the cost of the *nutrient adequate diet*, and almost 5 times the cost of the *energy sufficient diet* (FAO et al., 2020).

On this basis, one can conclude that those who have limited means to get food face two challenges: the first concerns the ability to reach the adequate intake of calories in terms of quantity, and the second refers to the healthy content of such calories, thus to the capacity to assimilate the recommended quantities of each food group. Thereafter, income appears to be a crucial determinant in the demand of food – especially the healthy and diverse one – and thus countries belonging to several income groups are supposed to have different availability of food, both in terms of quantities and composition. In particular, the availability – and hence the consumption – of more nutritious and expensive food is proved to increase with the rising of income, suggesting that a shift in consumption patterns happens when a country's income grows (FAO et al., 2020).

In general, the quantity of food demanded is negatively associated with changes in food prices and positively associated with income changes. However, both elasticities differ across food items and are affected by substitution and income effects (FAO et al., 2020). In fact, the demand of staple foods (namely cereals, grains) is pretty inelastic with respect to both price and income, while the demand of nutritious food (like fruits, vegetables, and food of animal origin) presents greater elasticities, especially in poorer countries (FAO et al., 2020). Based on the above, diets in low-income countries are expected to be more reliant on cereals, roots and tubers, but to be deficient in proteins, particularly of animal origin. In fact, Table 3.3 shows that on average, over the period 2017-2019, the highest percentages of DES derived from cereals, roots, and tubers – comprised between 69 and 79 – were registered in ten low-income[32] and lower-middle income[33] countries. Moreover, some of these countries – namely Madagascar, Mozambique, Lesotho, Zambia, Timor-Leste – appeared also among the ones with high prevalence of undernourishment and/or inadequate dietary energy supply. In addition, the lowest quantities of protein of animal origin per capita[34] were supplied in nine countries located in the African continent, and in Haiti – all the ten are classified as low and lower-middle income

[32] According to the World Bank, Afghanistan, Ethiopia, Madagascar, Malawi, Mozambique, and Sierra Leone are classified as 'low-income countries'. See https://data.worldbank.org/country/XM, accessed October 2020.

[33] According to the World Bank, Bangladesh, Lesotho, Timor-Leste, and Zambia are classified as 'lower-middle- income countries'. See https://data.worldbank.org/country/XN, accessed October 2020.

[34] According to FAO, the national average protein supply (expressed in grams per caput per day) includes the following groups: meat; offals; animal fats and products; milk and products; eggs, fish, seafood and products; and aquatic products, other.

countries – denoting again that the quality of the diet – concerning in this instance the capability to supply and consequently to afford proteins-rich food – is strictly dependent on income.
Finally, the ten countries that in the period 2016-2018 registered the smallest value per capita of food net production – in constant 2004-06 international dollars – are illustrated, to provide a measure of the economic size of the food production sector in these countries. The ranking is actually led by the special administrative Chinese regions Macao (3) and Hong Kong (5), along with Singapore (5), thus suggesting that these territories rely heavily on imports to satisfy internal food demand. This is not surprising considering that their relatively small land areas, mostly urban, have the highest population density in the world[35]. Other countries belonging to the Asia and Middle East region are mentioned in the list – namely Maldives, Qatar, Bahrain – as well as territories from other parts of the world, such as Greenland, Bermuda, Equatorial Guinea, Saint-Kitts and Nevis.

3.2.2 Access

Given the physical or potential availability of food, it becomes necessary to investigate if people are able to afford it. The Food Insecurity Experience Scale (FIES) is a tool developed by the FAO aimed at measuring access to food through specific questionnaires submitted to a representative sample of the adult population whose answers are then converted, through the use of advanced statistical techniques, into quantitative measures that are placed on a scale of severity (FAO et al., 2020, p. 193). The lack of food access measured by the FIES is associated with two levels of severity of food insecurity: moderate and severe. According to the FIES, people living in conditions associated with moderate food insecurity "face uncertainties about their ability to obtain food and have been forced to reduce, at times during the year, the quality and/or quantity of food they consume due to lack of money or other resources. […] which diminishes dietary quality, disrupts normal eating patterns, and can have negative consequences for nutrition, health and well-being" (FAO et al., 2020, p. 255). Instead, people in severe food insecurity "have likely run out of food, experienced hunger and, at the most extreme, gone for days without eating, putting their health and well-being at grave risk" (FAO et al., 2020, p. 256).
The first two columns of Table 3.4 report the countries that recorded the highest prevalence of food insecurity – both at severe, and at moderate or severe levels – in the three-year period 2017-2019. In particular, this prevalence expresses in both cases the percentage of individuals in the population living in households in which at least one member is classified as severely and moderately or severely

[35] In 2018 the World Bank World Development Indicator 'Population density (people per sq.km of land area)' registered the highest values in Macao (20,777), Singapore (7,953), and Hong Kong (7,096). See https://data.worldbank.org/indicator/EN.POP.DNST, accessed December 2020.

food insecure, respectively (FAO et al., 2020). Nine out of the ten countries with the highest prevalence of severe food insecurity also exhibit the highest prevalence of moderate or severe food insecurity (all except Namibia, replaced by Uganda). In both rankings, Africa is the only continent represented, proving that, globally, the most extreme difficulties in accessing food are concentrated in the African territories. In particular, South Sudan, Liberia and Malawi appear at the top, recording percentages of severe food insecurity higher than 50%, and moderate or severe food insecurity greater than 82%. As already mentioned above, income is an important determinant of access to food, therefore a country's per capita wealth is a significant proxy in this regard. In effect, what is apparent from the last column of Table 3.4 is that in 2019 the lowest GDP per capita – based on Purchasing Power Parity (PPP) in constant 2017 international dollars – was recorded in African countries. Among these, those that do not appear among the countries with the highest percentages of moderate or severe food insecurity are not listed due to unavailability of data, as well as it should be noted that for South Sudan – ranked first and second in the first two columns – there are no recent data on GDP per capita.

Table 3.4. The access dimension of food security

Countries Ranking (the first place corresponds to the worst condition)	**Prevalence of severe FI* 2017-2019 (% population)**	**Prevalence of moderate or severe FI 2017-2019 (% population)**	**GDP per capita, PPP** 2019 (constant 2017 I$)**
1	South Sudan (63.7)	Liberia (88.5)	Burundi (752)
2	Liberia (60.4)	South Sudan (84.9)	Central African Rep. (945)
3	Malawi (51.8)	Malawi (82.2)	Malawi (1,060)
4	Guinea (49.7)	Sierra Leone (81.4)	Congo, Dem. Rep. (1,098)
5	Botswana (41.2)	Guinea (74.1)	Niger (1,224)
6	Mozambique (40.7)	Mozambique (68.4)	Mozambique (1,281)
7	Zimbabwe (34.2)	Botswana (66.7)	Liberia (1,428)
8	Sierra Leone (31.8)	Zimbabwe (66.7)	Chad (1,580)
9	Namibia (31.3)	Uganda (66.3)	Togo (1,597)
10	Eswatini (30)	Eswatini (63.3)	Madagascar (1,647)

* FI stands for Food Insecurity.
** PPP stands for Purchasing Power Parity.
Sources: Suite of Food security indicators, FAO (2020a); GDP per capita, PPP (constant 2017 international $), World Development Indicators, World Bank (2020b).

3.2.3 Utilization

Once food is available and accessible – then when the first two dimensions are accomplished – the *utilization* of food becomes relevant, which is strictly related to the concept of nutrition security.

Indeed, with reference to the nutritional status of individuals, the SDG 2.2 sets the objective of ending all forms of malnutrition by 2030 (United Nations, 2015), where malnutrition, as previously described, results from a diet that is considered inadequate either by excess or by deficiency of nutrients. The undernutrition issue, which reflects the latter status, is of particular concern especially for children. Therefore, the United Nations International Children's Emergency Fund (UNICEF), the World Health Organization (WHO) and the World Bank monitor the prevalence of stunting[36] among children under the age of five in order to capture a facet of malnutrition particularly dangerous in the early stage of an individual's development. In fact, as *The State of Food Security and Nutrition in the World 2020* report underlines, this indicator "reflects the cumulative effects of undernutrition and infections since and even before birth. It may be the result of long-term nutritional deprivation, recurrent infections and lack of water and sanitation infrastructures" (FAO et al., 2020, p. 196).

The highest percentages of stunted children – according to the latest data available – were registered in Africa, in particular in Burundi (54), Niger (48.5), Madagascar (41.6), and Malawi (39). Severe prevalence of stunting – higher than 34% – were registered also in other countries located in the African continent – namely Central African Republic, Nigeria, Ethiopia, Lesotho – and in Southern Asia – particularly in Afghanistan and Pakistan.

Beside undernutrition, overweight constitutes another facet of malnutrition which implies a bad nutritional status of the individual, for this reason some indicators related to this aspect are also monitored to explore the issue as a whole. As illustrated in Table 3.5, in 2016 the ten highest prevalence of obesity in the adult population[37] were registered in Pacific islands and microstates located in Oceania. These territories, not densely populated, have been experiencing significant nutritional problems for many years. In fact, these territories have seen their traditional diets profoundly changed as a result of the massive increase in food imports, especially of processed food (Snowdon and Thow, 2013). This evidence is, moreover, consistent with what was pointed out by Drewnowski and Popkin (1997, p. 31), namely that "food imports, fast foods, and a rising

[36] The prevalence of stunting is the "percentage of under-fives falling below minus 2 standard deviations (moderate and severe) from the median height-for-age of the reference population", based on the WHO's Child Growth Standards 2006 (UNICEF, WHO and World Bank, 2020).

[37] According to the WHO, the prevalence of obesity in the adult population is "the percentage of adults aged 18 and over whose Body Mass Index (BMI) is more than 30 kg/m2"; see https://www.who.int/data/gho/indicator-metadata-registry/imr-details/2389 accessed October 2020.

consumption of sugars and animal fats are sometimes held to be responsible for the rising global rates of obesity and associated chronic disease".

Table 3.5. The utilization dimension of food security

Countries Ranking (the first place corresponds to the worst condition)	**Prevalence of stunting 2018/2019* (% children < 5 years old)**	**Prevalence of obesity 2016 (% adult population)**	**People using at least basic drinking water services 2016/2017** (% population)**
1	Burundi (54)	Nauru (61)	Chad (39)
2	Niger (48.5)	Cook Islands (55.9)	South Sudan (41)
3	Madagascar (41.6)	Palau (55.3)	Ethiopia (41)
4	Malawi (39)	Marshall Islands (52.9)	Papua New Guinea (41)
5	Afghanistan (38.2)	Tuvalu (51.6)	Congo, Dem. Rep. (43)
6	Pakistan (37.6)	Niue (50)	Central African Republic (46)
7	Central African Republic (37.5)	Tonga (48.2)	Burkina Faso (48)
8	Nigeria (36.8)	Samoa (47.3)	Uganda (49)
9	Ethiopia (36.8)	Kiribati (46)	Niger (50)
10	Lesotho (34.6)	Micronesia, Federated States of (45.8)	Eritrea (52)

* 2018 is the reference year for all countries except for Burundi and Ethiopia, whose values refer to 2019.
** 2017 is the reference year for all countries except for Central African Republic and Eritrea, whose values refer to 2016.
Sources: Joint child malnutrition estimates, UNICEF, WHO, and World Bank (2020); Prevalence of obesity among adults, Global Health Observatory data repository, World Health Organization (2017); Estimates on the use of water, sanitation and hygiene by country, Joint Monitoring Programme for Water Supply, Sanitation and Hygiene, WHO and UNICEF (2019).

In order to ensure a good nutritional status of the individual, some essential services are needed, first and foremost access to safe and uncontaminated water. Indeed, having access to safe water prevents the spread of water-borne diseases that, in some cases, lead to death, and which are still at very high levels in countries affected by widespread poverty and insufficient sanitary services. The last column of Table 3.5 lists the ten countries that in 2016-2017, according to the latest data collected by the Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene – a collaboration between the WHO and UNICEF – had the smaller percentage of people using at least basic drinking water services[38]. All the countries mentioned in the ranking are located in the Sub Saharan Africa and

[38] According to the WHO, the percentage of population using at least basic drinking water services is "the population that drinks water from an improved source, provided collection time is not more than 30 minutes for a round trip. This indicator encompasses both people using basic drinking water services as well as those using safely managed drinking water services. Improved water sources include piped water, boreholes or tubewells, protected dug wells, protected springs, and

have registered percentages below 52, denoting that the region has been suffering considerable hardship in accessing water of acceptable quality, and this inevitably exacerbates food insecurity conditions on these territories.

3.2.4 Stability

The comprehensive dimension of stability ensures that households are constantly food secure, despite the adverse impacts that climatic, economic, social, and political factors could have on any of the aforementioned aspects of food security (availability, access, and utilization). In particular, the overall system is repeatedly exposed to short-term and medium-to long-term instability, which eventually culminate in acute and chronic food insecurity, respectively (FAO et al., 2020).

For many countries trade is certainly a fundamental component in the achievement of food security, especially for those that are not food self-sufficient. Nevertheless, trade exchanges expose the negotiators involved to external shocks and various forms of dependence, which constitute a threat to their general stability, and – with a focus on the topic of the current analysis – to the stability of their food systems. Therefore, FAO (2020a) supervises some relevant indicators able to reflect the status of dependence and vulnerability of countries, by monitoring – among others – the dependence on imports for the domestic supply of cereals and the sufficiency of foreign-exchange reserves needed to pay for food imports. Table 3.6 – based on data related to a three-year average for the period 2015-2017 – ranks countries according to their level of exposure to potential sources of instability that, for both the indicators considered, are associated with high scores. In particular, ten countries were found to be totally import-dependent for their national supply of cereals, namely Mauritius and Cabo Verde in the African continent, Kuwait and the United Arab Emirates located in the Middle East region, and other Caribbean countries. While it is understandable that these countries might not have the productive capacity to satisfy the domestic demand for cereals – due to natural resources' constraints – it must be recognized that a total dependence on imports is a cause of high vulnerability.

Similarly, the ratio of the value of food imported to the value of merchandise exported measures to what degree a country is vulnerable to external shocks that may occur on international markets. In fact, a high ratio suggests a disequilibrium of the two flows, which in turn may indicate a lack of foreign exchange reserves – collected through the export channel – essential to pay for food imports. The highest percentage was recorded in Djibouti, where the value of food imports in 2015-2017 was seven times greater than that of merchandise exports. In fact, the country located in the Horn of Africa

packaged or delivered water"; see https://www.who.int/data/gho/indicator-metadata-registry/imr-details/4818, accessed October 2020.

faces challenging climatic conditions – dry weather, poor rainfalls, scarce water – which undermine agricultural production (already constrained by scarce arable land). Consequently, the country is forced to import the 90% of the food it needs and is very sensitive to any alteration of food prices on international markets (World Food Programme, 2021). The other nine countries mentioned in the ranking show very high values as well; among them, Afghanistan and Somalia draw attention as they appeared also in previous tables illustrated in this chapter. In particular, in 2019 Afghanistan had the third highest number of people classified as in crisis of worse according to the IPC/CH protocol; in addition, the country held a high prevalence of stunting among children in 2018. Somalia, according to latest data on food availability, ranked first – corresponding to the lowest score – in the DES adequacy, and more generally in recent years the country has been suffering from conflicts, political instability, but also severe droughts (FSIN, 2020).

Table 3.6. The stability dimension of food security

Countries Ranking (the first place corresponds to the most vulnerable condition)	**Cereal import dependency ratio* 2015-2017 (%)**	**Value of food imports** 2015-2017 (% value of merchandise exports)**	**Arable land equipped for irrigation 2015-2017 (% total arable land)**
1	Mauritius (100)	Djibouti (701)	Egypt (100)
2	Cabo Verde (100)	Bermuda (677)	Seychelles (100)
3	Kuwait (100)	Timor-Leste (544)	Sao Tome and Principe (100)
4	United Arab Emirates (100)	Comoros (419)	Tajikistan (100)
5	Barbados (100)	Afghanistan (355)	Turkmenistan (100)
6	Dominica (100)	Cabo Verde (299)	Uzbekistan (100)
7	Grenada (100)	Somalia (276)	Bahrain (100)
8	Saint Kitts and Nevis (100)	Kiribati (261)	Georgia (100)
9	Saint Vincent and the Grenadines (100)	San Tome and Principe (239)	Kuwait (100)
10	Trinidad and Tobago (100)	Tonga (231)	Oman (100)

* It is computed as: (cereal imports – cereal exports)/ (cereal production + cereal imports – cereal exports) * 100. The maximum value is then 100 and negative values indicate that the country is a net exporter of cereals (FAO, 2020a).
** Food imports do not include fish.
Source: Suite of Food security indicators, FAO (2020a).

However, instability does not only derive from market mechanisms, but also from the geographical context and the natural characteristics of territories. In fact, since the agricultural system is very sensitive to climatic events and water availability, it becomes essential to develop strategies to reduce

risks able to threaten food production, and hence food security. Among many techniques, the establishment of irrigation systems – particularly needed in water-deficient areas – allows to deal with scarce rainfalls and droughts.
Thereby, the percentage of land equipped for irrigation[39], even if not always equal to the area actually irrigated, provides a measure of the dependence of countries on irrigation, a crucial practice to cope with the above-mentioned shocks, but as well a measure of the vulnerability to water shortages and water stress conditions. Table 3.6 therefore mentions the ten countries whose agricultural lands are totally equipped for irrigation: three of them are located in Africa, but the majority belongs to Central Asia and Middle East regions. The highest percentage was also recorded in Qatar, the United Arab Emirates, Saint Lucia, Ecuador, New Zealand, and New Caledonia.

3.3 Global trends in recent years

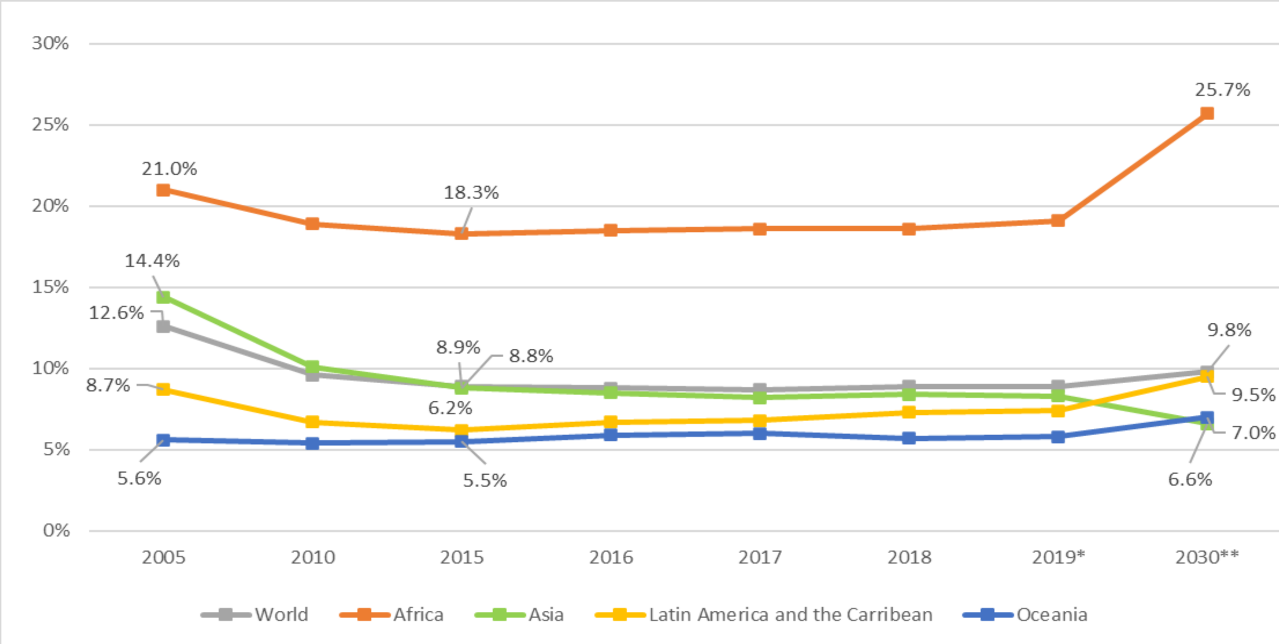
It has been emphasized several times in the preceding pages of this work that addressing the problem of food insecurity requires an extensive and multi-faceted effort that is well captured by the set of the 17 UN Sustainable Development Goals, first and foremost by SDG 2, but also many others. This paragraph aims to highlight the trends recorded in recent years at global and macro-regional level, with in some cases enriching forecasts for the year 2030, which are useful for understanding progress towards the goals of the 2030 Agenda. The first paragraph of this chapter began by reporting that the world in not moving in the right direction to achieve the targets associated with SDG 2, and in particular with Targets 2.1, monitored through the PoU and the Prevalence of Moderate or Severe Food Insecurity (Target 2.1.1 and 2.1.2 respectively) (FAO et al., 2020).

3.3.1 SDG Target 2.1.1

FAO et al. (2020) show how the PoU indicator, expressed in absolute and percentage terms, has been experiencing a global trend reversal since 2014. In fact, after a period of decline in global undernourishment, in 2014 the values began to rise again, and what is even worse is that the projections for the year 2030 only confirm this increasing trend (FAO et al., 2020, p.4).
It is interesting to take a closer look at the global trend, differentiating the aggregate figure by macro-region (Figure 3.1) to understand which areas are experiencing the greatest deterioration in their PoU.

[39] According to FAO, total arable land equipped for irrigation is “the area equipped to provide water (via irrigation) to the crops. It includes areas equipped for full and partial control irrigation, equipped lowland areas, pastures, and areas equipped for spate irrigation” (FAO, 2020a).

Figure 3.1. PoU in the world by region, 2005-2030



NOTES: values for 2019 and 2030 are the result of FAO projections; projections for year 2030 do not account for the impact of the COVID pandemic (FAO et al., 2020). Northern America and Europe are not included since their PoU over the whole time series does not exceed 2.5%.
Source: Author's elaboration based on FAO data, FAO et al. (2020), p. 9.

It is immediately apparent that the PoU is very high on the African continent (orange line), where values are well above the world average (grey line) throughout the time series, and where the steepest increase in PoU is expected by 2030. Specifically, the sub-Saharan area is the area that is suffering the most, not only because of deteriorating economic conditions and widespread poverty, but also because of the persistence of harsh conflicts. These latter are often exacerbated by changing environmental conditions, which fuel the competition for resources such as water and land (FAO et al., 2020, pp. 8-9). For instance, climate variability has reduced crop yields in Somalia and the Central African Republic, while extensive droughts has affected Madagascar, Zambia, Zimbabwe, South Africa (FAO et al., 2020, pp. 8-9).

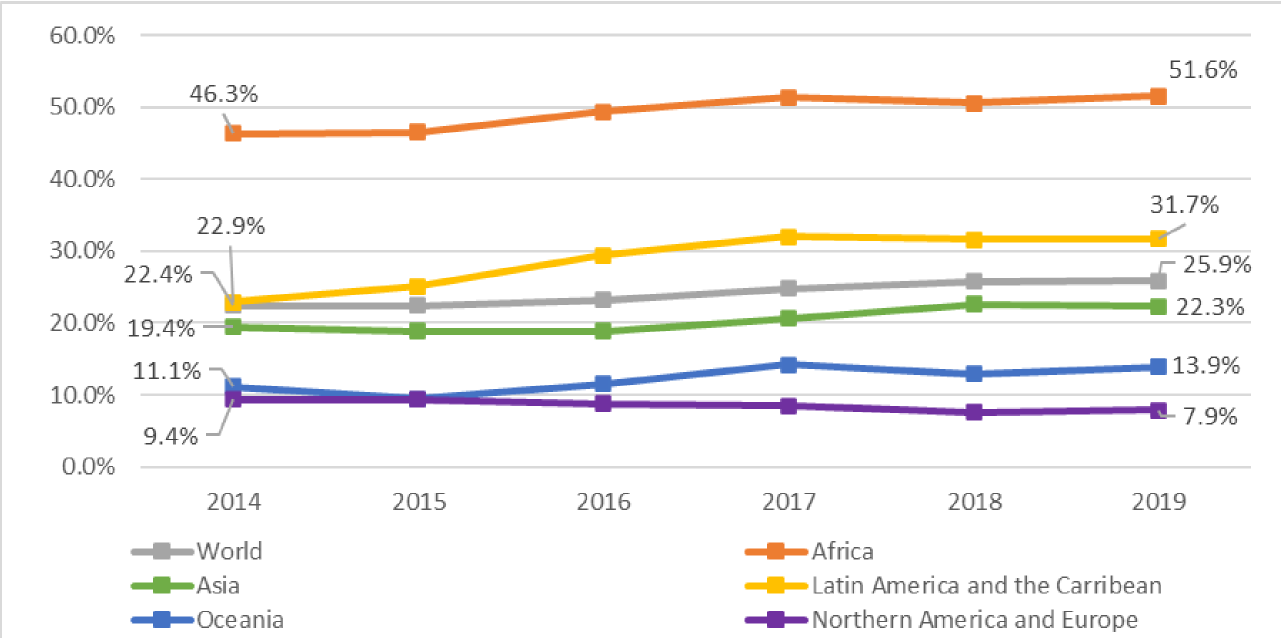
Asia (green line), which had the highest PoU after Africa in 2005 (14.4%), has improved markedly in recent years and is expected to improve further by 2030 (6.6%). The trend is driven mainly by progress in the south and south east areas, however the continent is still suffering in the west – particularly in the Syrian Arab Republic and Yemen – where there is a counter tend compared to the rest of the region (FAO et al., 2020, pp. 10-11). Finally, in the Latin America and Caribbean region (yellow line) the PoU has been substantially deteriorating since 2015, when it was 6.2%, and is projected to reach the 9.5% in 2030 (Figure 3.1). In particular, the highest PoU is recorded in the Caribbean – especially, Haiti is suffering from the continuous occurrence of extreme natural events and is dealing with the depletion of its natural resources – where nevertheless some modest progress

has been made. Instead, the Central and South America sub-regions have been experiencing an alarming deterioration of the PoU since 2015, specially in Venezuela (FAO et al., 2020, p. 14).
Also, what is noteworthy about the projections on the number of undernourished people in 2030 (FAO et al., 2020) is that Asia will be able to reduce the number of undernourished people, which is currently the highest in the world (381.1 million on a total of 687.8 million). Africa, on the other hand, will be home to the majority of undernourished people in the world (433.2 million on a total of 841.4 million).

3.3.2 SDG Target 2.1.2

On the prevalence of moderate or severe food insecurity in the population based on the FIES, FAO et al. (2020) report that the trend in recent years is not only failing to meet the goal of the 2030 Agenda, but also appears to be deteriorating. This indicator, which includes the cumulative probability of being in the conditions of moderate/severe food insecurity (see definitions in the section 3.2.2), has increased at global level from 22.4% in 2014 to 25.9% (corresponding to 2 billion people) in 2019. Furthermore, the report specifies that this increase has been mainly driven by the prevalence of *moderate* food insecurity, which, as already noted, has direct implications for the quality of diets and thus for malnutrition as a whole (FAO et al., 2020).

Figure 3.2. Prevalence of moderate or severe food insecurity in the world, by region, 2014-2019



Source: Author's elaboration based on FAO data, FAO et al. (2020), p. 20.

As in the case of the PoU, analyzing the indicator's performance on a regional basis makes it possible to extrapolate more detailed information. First of all, as shown in Figure 3.2, all regions of the globe, except north America and Europe (purple line), experienced an increase in the prevalence of moderate or severe food insecurity in 2019 compared to 2014. In addition, both Africa and Latin America and the Caribbean recorded higher prevalence of moderate or severe food insecurity than the world average over the period considered, reaching 51.6% and 31.7% respectively in 2019, with an increase of 8.8 percentage points over 2014 in the case of Latin America and the Caribbean (Figure 3.2). However, looking at the problem of moderate/severe food insecurity in absolute terms – i.e., in million people – shows that in 2019, of the 2 billion food insecure people in the world, 51.3% lived in Asia (largely in Southern Asia), 33.7% in Africa (mostly in Sub-Saharan Africa), 10.3% in Latin America and the Caribbean, 4.4% in Northern America and Europe, and 0.3% in Oceania (FAO et al., 2020, pp. 21-23).

3.4 The impact of the Covid-19 pandemic

The health and socio-economic crisis the world has been experiencing since the outbreak of the Covid-19 pandemic – officially declared on 11 March 2020 – is severely compromising the food security of millions of people. In June 2020, the United Nations (2020b) declared that those whose food and nutrition security is most threatened by the multiple consequences of the pandemic are those who were already at risk of food insecurity before the health crisis. Therefore, the activities of organizations such as the World Food Programme (WFP) have intensified in those contexts, which were already particularly vulnerable. Estimates made by the World Food Programme (2020c) itself tell us that in the first nine months of 2020, the number of people directly benefiting from food assistance (96.6 million) was about the same as those assisted in the entire year of 2019. Furthermore, in 79 of the countries where the WFP operates, the number of people experiencing acute food insecurity is expected to increase by 121 million due to the effects of the pandemic, reaching 270 million in 2021 (World Food Programme, 2020c).

The pandemic has affected, and will continue to affect, food security through multiple channels. Firstly, the restrictive measures taken to tackle the emergency have so far resulted in the loss of income for many people, which has severely compromised access to food. In particular, the loss of income has mainly affected the informal sector – whose workers are not protected by social security – which employs a large part of the workforce in low-income countries and the majority of the rural poor engaged in agriculture (FSIN and Global Network Against Food Crises, 2020). Producers of perishable commodities, whose products often could not reach wholesale markets, suffered significant losses that undermined their ability to invest in the following season's activities (United

Nations, 2020b). In addition, demand for perishable but more nutritious food commodities (such as meat, fish, dairy products, fruit and vegetables) contracted due to falling incomes, with serious repercussions for nutrition (FSIN and Global Network Against Food Crises, 2020).

The disruption of trade in times of Covid-19 affected the functioning of food systems, leading to a rise in food prices in some localities. In February 2021, the FAO Food Price Index[40] recorded an increase for the ninth consecutive month, reaching 116 points (increased by 16.7% compared to February 2020), the highest monthly value on record since July 2014 (FAO, 2021).

The Covid-19 crisis prompted some countries to impose restrictions on exports of agricultural commodities and foodstuffs, despite the fact that there were no signs of a contraction in food availability. In particular, in the early months of the pandemic, Russia and Kazakhstan (two major wheat exporters) imposed restrictions on wheat exports, and Vietnam (a major rice exporter) limited its rice exports (Laborde et al., 2020). Restrictions on exports of staple foods, such as rice and wheat, have major repercussions especially when implemented by major exporters of these commodities, i.e., those providing a significant portion of the total quantities traded on international markets. In general, such policies are detrimental to food security because they contribute to raising prices and disproportionately harm food-import dependent countries, especially low- and middle- income countries, where a large proportion of household income is spent on food (World Bank, 2021).

The current health crisis is affecting all countries in the world, but above all is acting as an additional stressor in contexts already exhausted by economic crises, conflict, extreme natural events and pest invasions. In this respect, WFP and FAO (2020) recently identified 20 countries considered most at risk of experiencing peaks of acute food insecurity in the immediate future due to a combination of multiple drivers, including, of course, the effects of the pandemic. These countries are Haiti, Venezuela, Sierra Leone, Mali, Niger, Burkina Faso, Sudan, Nigeria, Cameroon, Central African Republic, Democratic Republic of the Congo, South Sudan, Mozambique, Zimbabwe, Ethiopia, Somalia, Lebanon, Syrian Arab Republic, Afghanistan, Yemen. In particular, the most widespread risk drivers found in these countries – which become even more devastating when coupled with the pandemic – are increase in violence and conflict, macroeconomic crises and worsening purchasing power, intensified weather extremes caused by la Niña[41] phenomenon, the spread of the Desert

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[40] The FAO Food Price Index "is a measure of the monthly change in international prices of a basket of food commodities. It consists of the average of five commodity group price indices (cereals, dairy, meat, vegetable oils, sugar) weighted by the average export shares of each of the groups over 2014-2016" (FAO, 2021).

[41] La Niña, together with El Niño, are opposite extremes of the ENSO (El Niño/Southern Oscillation), which refers to changes in the climate pattern (sea surface temperature, atmospheric pressure, and ocean currents) of the Equatorial Pacific Ocean, which influences weather worldwide. La Niña, as opposed to El Niño, is characterized by abnormally cool waters in the Equatorial Pacific Ocean. https://www.noaa.gov/education/resource-collections/weather-atmosphere/el-nino (accessed March 3, 2021). La Nina will probably continue to produce its effects in the first months of 2021, altering

Locust, and difficulty in accessing humanitarian assistance (WFP and FAO, 2020). The region that is suffering the most from the overlapping of multiple stressors to food security is East Africa. In fact, acute food insecure people in the region are predicted to increase by 73% over pre-COVID-19 levels, as a result of the extraordinary convergence of the pandemic, floods, desert locust invasion, socio-economic challenges, and conflict (WFP and FAO, 2020).

According to WFP and FAO (2020), the countries where the combination of several factors makes the risk of famine (the most acute manifestation of food insecurity) a real possibility – hence the countries globally considered to be most at risk – are Yemen, Burkina Faso, South Sudan and north-eastern Nigeria. In some areas of these countries, access to humanitarian assistance is severely limited, or even non-existent. In Yemen, food insecurity – already severely compromised by years of conflict – is likely to be further exacerbated by the economic crisis and an increase in food prices, as well as by the contraction of both income opportunities and the inflow of remittances caused by the Covid-19 pandemic (WFP and FAO, 2020). In 2020 Burkina Faso suffered an increase in violence and conflict within its borders, which severely limited access to food and led to an increase in Internally Displaced Persons (IDPs). The country recorded twice as many people in food crisis or emergency in 2020 as in 2019, thus becoming one of the countries whose food security is currently most at risk (WFP and FAO, 2020). Food insecurity levels are of great concern also in South Sudan, a country ravaged by conflict, difficult access to humanitarian aid, frequent flooding episodes, and further devastated by the economic consequences of the pandemic (contraction of economic activities, reduced income from oil exports, increased inflation). Finally, the northern states of Nigeria are a food security hotspot due to the ongoing hostilities, which cause the displacement of many people, and the difficulties in accessing humanitarian assistance (WFP and FAO, 2020). Furthermore, the whole country has been greatly affected by the multiple consequences of the Covid-19 crisis, through the decline in remittances and earnings from oil exports, and the economic impacts of the restrictions imposed to limit the spread of the virus.

rainfall patterns worldwide and increasing the risk of heavy rainfall and flooding in some parts of the world, while increasing that of droughts in others (World Food Programme, 2020c).

CHAPTER IV.

ENVIRONMENTAL RISKS: EVIDENCES AND PREDICTIONS

There is strong evidence that environmental degradation is accelerating dramatically compared to the pre-industrial era, and that almost all countries in the world are experiencing challenging circumstances created by this phenomenon. Therefore, countries are called to respond promptly to the massive environmental hazards they face by predicting as much as possible their occurrence and impacts, and by trying to mitigate the negative consequences. This chapter aims to illustrate a portion of the current knowledge on the risks posed by the environment, by ranking countries worldwide – on the basis of the data available – with respect to their level of exposure, both past and future.

4.1 Global warming evidences and the impact of human activities

One of the most mentioned planet signals about the environmental changes that are taking place is the on-going process of rising temperatures. In fact, the Paris Agreement (UNFCCC, 2015) signed in 2015 by 195 Parties highlights the need to limit global warming below 2°C – above pre-industrial levels – and to make the effort to maintain it even lower, at 1.5°C, to avoid further dangerous impacts of climate change (art. 2). The first two columns of Table 4.1 report the mean surface temperature change – in degree Celsius – of the ten countries that have registered the highest increase in temperature in 2019, and on average in the period 1961-2019, with respect to a baseline climatology for the period 1951-1980 (FAO, 2020b). Data, published by the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) were collected by the Global Surface Temperature Change distributed by the National Aeronautics and Space Administration Goddard Institute for Space Studies (NASA-GISS).

In 2019 the largest mean annual temperature change, with respect to the baseline 1951-1980, was registered in countries located in the European continent. The top of the ranking is taken by the Svalbard and Jan Mayen islands, situated in the Arctic Ocean, and belonging to Norway, which suffered a 2.9°C increase in temperature. This value exceeds the one registered by Poland (2.66), on the second place, by more than 0.30°C. The gap is very impressive whether we consider that the other nine positions, from Poland (2.66) to Austria (2.37), are placed in an interval of about 0.30°C. From this evidence it appears that the Arctic is warming faster than the rest of the planet, consistent with the phenomenon known as *Arctic amplification*, which states that “temperature variability and trends in the Arctic region tend to be larger than trends and variability for the northern hemisphere or the globe as a whole" (Serreze and Barry, 2011, p.85).

The mean temperature change, by meteorological year, over the period 1961-2019 shows that the European continent and the Russian Federation are home to the ten countries that on average, during the period considered, registered the highest increase in mean surface temperature, from Serbia (1.51), Luxembourg (1.49) and Montenegro (1.48) to Belarus (1.4) and Lithuania (1.36).

Table 4.1. Temperature change and the impact of human activities

Countries Ranking (from the highest value to the lowest)	**Temperature change* 2019 (°C)**	**Mean Temperature change by meteorological year 1961-2019 (°C)**	**CO2 Emissions 2016 (000 kt)**
1	Svalbard and Jan Mayen (Norway) (2.9)	Serbia (1.51)	China (9,893)
2	Poland (2.66)	Luxembourg (1.49)	United States (5,006)
3	Belarus (2.66)	Montenegro (1.48)	India (2,408)
4	Lithuania (2.63)	Estonia (1.46)	Russian Federation (1,732)
5	Czechia (2.55)	Slovenia (1.42)	Japan (1,136)
6	Slovakia (2.46)	Belgium (1.42)	Germany (728)
7	Latvia (2.45)	Latvia (1.4)	Iran, Islamic Rep. (662)
8	Hungary (2.41)	Russian Federation (1.4)	Korea, Rep. (620)
9	Slovenia (2.38)	Belarus (1.4)	Saudi Arabia (563)
10	Austria (2.37)	Lithuania (1.36)	Indonesia (563)

* Temperature change registered with respect to a baseline climatology for the period 1951-1980.
Sources: FAOSTAT database, *Temperature change* domain, FAO (2020b); *CO_2 emissions (kt)*, World Development Indicators, World Bank (2020a).

Another pillar of the Paris Agreement (UNFCCC, 2015) concerns the urgent need to reduce carbon dioxide emissions – CO_2 emissions – to achieve the long-term temperature goal. However, the Agreement leaves to each Party the burden to determine its own ambition target through *nationally determined contributions*, and it also recognizes that it might take longer for developing countries to cut emissions (art. 4).

Column three in Table 4.1 lists the ten major CO_2 polluters in the world in 2016 as reported by the World Bank, based on data provided by the Carbon Dioxide Information Analysis Center of the United States. The carbon dioxide emissions included in this indicator derive from fossil fuels combustion and cement manufacturing, and constitute the majority of greenhouse gas emissions that contribute to global warming and climate change (World Bank, 2020a).

In 2016 China and the United States, the two largest economies in the world, accounted for the 63% of the total CO_2 emitted by the ten largest carbon emitters – they emitted respectively 9,893,000 kt and 5,006,000 kt of carbon dioxide. It is worthy to highlight that the United States, the second largest carbon emitter, announced in 2017 the withdrawal from the Paris Agreement and, after the formal notice of intention dated 2019, the effective exit happened in November 2020.[42] However, the new President-elect Joe Biden recently announced that the American re-enter into the Paris agreement represents one of the priorities of his term of office[43]. This reversal of direction is crucial to the success of the Paris Agreement, which would inevitably be weakened by the absence of one of the world's major powers.

In order to undertake a more environmentally sustainable path, in the framework of a climate change mitigation strategy, it is essential to dramatically reduce the dependency on fossil fuels, whose combustion emits air pollutants that are harmful both for the environment and for public health. Nevertheless, the reliance on fossil fuels is at the base of our economies, and inverting this tendency is not an easy matter. Considering that the combustion of fossil fuels is really harmful for human health because it releases toxic substances that deteriorate air quality, the World Health Organization (WHO) is concerned with investigating the relationship between ambient air pollution and the death rate related to some diseases. In the first column of Table 4.2 a ranking is shown to emphasize the countries that in 2016 – year for which the most recent data are available – registered the highest death rate associated with ambient air pollution (World Health Organization, 2018). The value for each country was obtained following a two-step procedure. First of all, the World Health Organization (2018) combined information to measure the level of exposure to ambient air pollution in every country. In order to do this, they considered that the mean estimates of particulate matter, modelled using a combination of estimates from different data sources, were a good measure of exposure. Then, the fraction of some diseases – namely, lower respiratory infections, trachea, bronchus, lung cancers, ischemic heart disease, stroke, chronic obstructive pulmonary disease – that could be attributable to the exposure was estimated. Finally, the number of deaths attributable to ambient air pollution – and associated with these diseases – could as well be computed.

[42] See the press statement released by the American secretary of state Michel R. Pompeo, *On the U.S. Withdrawal from the Paris Agreement*, released in November 2019. Available at https://www.state.gov/on-the-u-s-withdrawal-from-the-paris-agreement/, accessed July 2020.
[43] See the *Statement by President-elect Joe Biden on the Five-Year Anniversary of the Paris Agreement* released in December 2020. Available at https://buildbackbetter.gov/press-releases/statement-by-president-elect-joe-biden-on-the-five-year-anniversary-of-the-paris-agreement/, accessed January 2021.

Table 4.2. Environmental impacts on human health

Countries Ranking (from the highest value to the lowest)	**Ambient Air Pollution attributable death rate 2016 (per 100'000 population)**	**Deaths attributable to the environment 2012 (in '000)**	**Deaths attributable to the environment 2012 (% total deaths*)**
1	Ukraine (124)	China (2,987)	Laos (32)
2	Bulgaria (121)	India (2,912)	North Korea (31)
3	Georgia (119)	Nigeria (498)	China (30)
4	Belarus (105)	Indonesia (350)	India (30)
5	North Korea (89)	Russian Federation (350)	Niger (28)
6	Bosnia and Herzegovina (87)	Pakistan (331)	Democratic Rep. of Congo (27)
7	Moldova (86)	United States (282)	Mali (27)
8	Romania (84)	Democratic Rep. of Congo (248)	Bosnia and Herzegovina (27)
9	Chad (83)	Bangladesh (201)	Mongolia (27)
10	Latvia (83)	Brazil (196)	Angola (26)

* Deaths related to the infectious, parasitic, neonatal and nutritional diseases, non-communicable diseases and injuries included in the analysis by the World Health Organization (2016).
Sources: *Ambient air pollution attributable death rate*, Global Heath Observatory Data Repository, World Health Organization (2018); *Deaths attributable to the environment*, Global Health Observatory Data Repository, World Health Organization (2016).

All the above-mentioned diseases have been considered for ranking the countries that have registered the highest death rate (per 100,000 population) associated with ambient air pollution. Ukraine (124), Bulgaria (121) and Georgia (119), three countries overlooking the Black Sea, appear at the top of the ranking. In general, the European continent, with eight countries – Ukraine, Bulgaria, Georgia, Belarus (105), Bosnia and Herzegovina (87), Moldova (86), Romania (84) and Latvia (83) – is strongly represented in this list, denoting that air quality is a concerning issue in this area.

A broader environment-related risk of death is also computed by the World Health Organization (2016), by accounting for the number of deaths, in absolute and percentage terms, that could have been avoided through the modification of the environment. According to the World Health Organization, a modifiable environment includes air, soil and water pollution with chemicals or biological agents, ultraviolet and ionizing radiation, built environment, noise, electromagnetic fields, occupational risks, agricultural methods, irrigation schemes, anthropogenic climate changes, ecosystem degradation, individual behaviors related to the environment, such as hand-washing, food contamination with unsafe water or dirty hands (World Health Organization, 2016). Most recent data, reported in the last two columns of Table 4.2, refer to 2012 and are based on the fraction of disease that can be attributed to the environment and could have been prevented for some infectious, parasitic, neonatal and nutritional diseases, non-communicable diseases and injuries.

China and India, at the first and second place of the ranking based on absolute values (expressed in thousands), suffered a huge number of fatalities attributable to the environment, with respectively 2,987,000 and 2,912,000 losses. The third place, with significantly fewer deaths, is taken by Nigeria (498,000).

In percentage terms, Laos and North Korea show the highest percentages of deaths attributable to the environment – respectively 32 and 31 per cent – followed immediately by China (30%) and India (30%). Some African countries also appear in this ranking, namely Niger (28%), Democratic Republic of Congo (27%), Mali (27%) and Angola (26%). Bosnia and Herzegovina (27%) is the only country located in the European Continent which appears among the ten highest values.

4.2 Extreme weather events: past evidences and future threats

Article 8.1 of the Paris Agreement (UNFCCC, 2015) states that "Parties recognize the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage". This statement was an important step towards the full consciousness, of all countries, of the necessity to consider the consequences of climate change as a concrete danger for people, assets, and economies. This is especially crucial given that there is growing evidence proving that the intensity and frequency of extreme weather events keep rising year by year. Accordingly, there are several scientific tools that report data on extreme natural events occurred in the past, as well as predictions on future vulnerabilities.

4.2.1 The German Watch CRI

The Non-Governmental Organization German Watch publishes annually a report to illustrate which countries suffered the heaviest impacts caused by extreme weather events in previous years. Weather related events considered in the analysis are storms, floods, temperature extremes and heat and cold waves (Eckstein et al., 2019). To carry out this analysis, the organization has developed a tool called the Climate Risk Index (CRI) composed by four indicators (relative weights): number of deaths (1/6), number of deaths per 100,000 inhabitants (1/3), sum of losses in US$ in PPP (1/6), losses per unit of GDP (1/3). Each country's index score derives from that country's average ranking in all the four indicators and the lowest score corresponds to the highest ranking, namely to the most impacted country (Eckstein et al., 2019).

Table 4.3 illustrates the latest countries rankings based on the CRI calculated by German Watch. The

Climate Risk Index 2020, in the first column, refers to extreme weather events occurred in 2018. Heatwaves were one major cause of damage in 2018 – in particular, Germany, Japan, and India suffered from extended periods of heat.[44] Japan, at the top of the list, suffered from heavy rainfalls, a severe heatwave, and a tropical cyclone in 2018. The Philippines, in the second position, was hit by a category five typhoon in 2018 and Germany, in the third place, recorded its hottest year in 2018. In fact, the heatwave that hit the European country caused more than 1,200 deaths and the scarce summer rainfalls generated dry soils whose negative consequences were especially perceived in October 2018, with massive economic losses for farmers (Eckstein et al., 2019).

Table 4.3. Quantified impacts of extreme weather events occurred in 2018 and in 1999-2018

Countries Ranking (from the most affected to the least)	**Climate Risk Index 2018**	**Long term Climate Risk Index 1999-2018**
1	Japan (5.50)	Puerto Rico (6.67)
2	Philippines (11.17)	Myanmar (10.33)
3	Germany (13.83)	Haiti (13.83)
4	Madagascar (15.83)	Philippines (17.67)
5	India (18.17)	Pakistan (28.83)
6	Sri Lanka (19.00)	Vietnam (29.83)
7	Kenya (19.67)	Bangladesh (30.00)
8	Rwanda (21.17)	Thailand (31.00)
9	Canada (21.83)	Nepal (31.50)
10	Fiji (22.50)	Dominica (32.33)

Source: *Global Climate Risk Index 2020*, Eckstein et al. (2019), German Watch.

In column two, the long-term Climate Risk Index shows the countries that have been most affected by extreme weather events in the period 1999-2018. These ten countries belong to two categories: the ones which have a high ranking due to exceptional catastrophes – such as Myanmar and Puerto Rico – and the ones which are continuously affected by extreme natural events – such as Haiti, the Philippines, Pakistan (Eckstein et al., 2019). Although this ranking gives a general idea of the main impacts of extreme weather events on people and economies, it lacks to consider the indirect effects of such events, such as the results of droughts and food scarcity. Thus, the negative impacts estimated

[44] According to Eckstein et al. (2019) heatwaves are defined as periods of abnormally hot weather, spanning at least five consecutive days with a temperature of 5°C above average.

by the index could be underrepresented, and also the results should be interpreted with caution considering that data across countries are often heterogenous in terms of collection methodology, accuracy, and quality. Moreover, low on-set processes, such as rising sea levels and warmer oceans, are not captured by the CRI, which however remains a useful tool to summarize past data, even if unable to predict future vulnerabilities.

4.2.2 The European Extreme Events Climate Index

Extreme events cause substantial loss of human life, but also massive economic damage. In this context it becomes therefore essential to have a wide availability of scientific data in order to spread information about them and enable greater understanding of the effects of these phenomena on assets and economies. It is precisely with these purposes that the International Foundation Big Data and Artificial Intelligence for Human Development (IFAB) – located in the Bologna Data Valley – sponsored the European Extreme Events Climate Index (E^3CI), presented for the first time in January 2021. The E^3CI is a synthetic tool which measures the impacts of five weather induced hazards (heat stress, cold stress, droughts, extreme precipitations, extreme winds) at the country level (IFAB, 2021). It results from the partnership between a scientific research center, the Euro-Mediterranean Center on Climate change (CMCC), and Leithà, a tech-insurance company of the Unipol Group. Input data on weather events used to obtain the index are taken from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis, a daily updated global dataset on Earth's climate, with observations from 1950 to present (IFAB, 2021). The E^3CI results from the mean of the values of its five components (heat stress, cold stress, droughts, extreme precipitations, extreme winds). The values of the components are released monthly and express standardized anomalies with respect to their reference value in the baseline period 1981-2010 (IFAB, 2021).

The importance of tools such as the E^3CI lies not only in the ability to disseminate information on past extreme natural events per se, but in providing criteria for assessing the exposure of assets to such risk events. The information that can be extracted from scientific data becomes fundamental, for example, for the development of insurance policies against natural disasters and for the design of new financial instruments. Moreover, such information can serve as a basis for guiding risk management decisions and actions.

4.2.3 Future vulnerabilities

Alongside measures that report past data on extreme natural events – such as the CRI and the E^3CI – there are also tools that attempt to make predictions about future vulnerabilities. For example, there is a useful instrument, *Aqueduct Floods*, which allows to analyze current and projected future flood risks, also holding in consideration the role played by climate variability and socioeconomic development. It is provided by the collaboration among the World Resources Institute (WRI), Deltares, the Institute for Environmental Studies of the VU University Amsterdam, Utrecht University and PBL Netherlands Environmental Assessment Agency (Kuzma and Luo, 2020).

According to the WRI, economic growth and urbanization are putting more and more people into flood-prone areas (Kuzma and Luo, 2020). Starting from this premise, it is essential to predict future threats in order to mitigate the risks. Risk is calculated as a combination of three dimensions: affected population, affected GDP and urban damage. Focusing on the risk for the affected population, flood risk can be divided into riverine flood risk and coastal flood risk. According to the WRI, the riverine and the coastal flood risk measure the population expected to be affected by riverine and coastal flooding respectively in an average year, accounting for existing flood-protection standards (Hofste et al., 2019). Flood risk is assessed using hazard (inundation caused by river overflow and storm surge), exposure (population in flood zone), and vulnerability (for example forced migration and fatalities). Higher values indicate that on average a greater proportion of the population is expected to be impacted by riverine and coastal floods (Hofste et al., 2019).

As stated by Kuzma and Luo (2020), the number of people affected by flooding will double in 2030 compared to the 2010 baseline scenario. The first two columns of Table 4.4 rank countries that are expected to experience the largest increase in annual population exposed to flooding – riverine flooding in the first column, coastal flooding in the second one – in 2030 compared to the 2010 baseline scenario. Bangladesh is at the very first positions of both rankings, with an increase of 8 million with respect to riverine flooding, and 2 million with reference to coastal flooding. India is by far the country that will suffer the highest increase of people affected by riverine flooding, equivalent to 22 million people annually. In broad terms, Asia and Africa are the continents that will be most vulnerable to the risk of flooding, both riverine and coastal. In fact, the majority of the countries included in the two rankings are located in these continents, except for the Netherlands, which by 2030 will have 170,000 more people at risk of coastal flooding annually.

Floods are extreme water-related events, but there is also a slow worrying water-related phenomenon which is capturing global attention: the rising of sea levels. Scientific studies report that the Intergovernmental Panel on Climate Change (IPCC) states that the main contributors to sea level rise since 1993 are the warming of oceans and the melting of glaciers – with loss of Antarctica and Greenland’s ice sheets (Gehrels, 2016). These studies also demonstrate that a portion of global sea level rise can be attributed to anthropogenic forcing – in particular, to greenhouse gas emissions – and namely, that the increasing trend is not driven by natural processes alone (Gehrels, 2016). The negative consequences of higher sea levels are manifold, from flooding to salinization, and the vulnerability of people living in coastal areas should be carefully taken into account.

Table 4.4. Predictions on future risk of flooding and rising sea level impacts

Countries Ranking (from the highest value to the lowest)	**Expected increase in annual flood-affected population 2030 compared to 2010 (million people)**		**SLR* Vulnerability** (current population, in millions, exposed to an average annual flood in 2050)
	Riverine flooding	**Coastal flooding**	
1	India (22)	Bangladesh (2)	China mainland (93)
2	Bangladesh (8)	Vietnam (1.4)	Bangladesh (42)
3	Pakistan (3.8)	Indonesia (0.9)	India (36)
4	Indonesia (2.8)	India (0.7)	Vietnam (31)
5	Egypt (2.9)	China (0.5)	Indonesia (23)
6	Nigeria (2.3)	Nigeria (0.4)	Thailand (12)
7	Vietnam (1.6)	Philippines (0.28)	Philippines (6.8)
8	Sudan (1.5)	Egypt (0.18)	Netherlands (5.5)
9	Afghanistan (1.4)	Netherlands (0.17)	Japan (5.3)
10	Ethiopia (1.3)	Malaysia (0.12)	Egypt (4.2)

* SLR stands for Sea Level Rise.
Sources: Kuzma and Luo (2020), World Resources Institute; Climate Central (2019).

Climate Central (2019), an independent organization of scientists and journalists, recently reported that previous assessments of global vulnerability to sea level rise underestimated the real threat. Based on the scientific findings published on Nature Communications by Kulp and Strauss, the report shed light on the importance of considering land elevation when assessing future sea-level rise threats. When accurate data on land elevation are not available, it becomes difficult to predict the real threats faced by coastal communities. The new model on which the report is based, *CoastalDEM*, shows that many coastlines are lower than what it was believed, and thus that coastal flooding could affect much more people in the future than previously thought (Climate Central, 2019). In the past, data were usually obtained from a NASA project called ‘Shuttle Radar Topography Mission’ (SRTM). However, this model usually overestimated elevation – of 15.5 feet on average – as it was not able to distinguish the top of buildings and trees from the actual ground. *CoastalDEM*, based on SRTM 3.0, aims to reduce the error in the estimation – cutting it to less than 2.5 inches – and hence to produce improved data on coastal elevation which, combined with sea level rise models, allows to obtain better estimates of exposure to rising seas (Climate Central, 2019). *CoastalDEM* estimates that 300 million people will live below average annual coastal flood levels by 2050. Furthermore, data indicate that people living in the six most vulnerable countries account for the 75% of the total population exposed worldwide (Climate Central, 2019). The third column of Table 4.4 shows the ten countries that have the largest number of people which currently live below the elevation of an average annual coastal flood in 2050, based on *CoastalDEM* estimates. China ranks at the top of the list, with 93 million people endangered, followed by Bangladesh (42), India (36), Vietnam (31), Indonesia (23), Thailand (12), Philippines (6.8), Netherlands (5.5), Japan (5.3), and Egypt (4.2). Once again, the data show that the worst effects of coastal flooding on population will be felt in Asia.

4.3 The water-stress issue

Water is a fundamental resource for humans and their livelihoods; however, the relentless growth of its demand is challenging the water management system. Indeed, some researchers of the World Resources Institute reported that the ever-increasing water demand has meant that since 1960s global water withdrawals have more than doubled (Hofste, Reig, and Schleifer, 2019), putting several areas worldwide under water stress conditions.

The above-mentioned *Aqueduct* digital platform, developed by the WRI, allows to estimate the most water-stressed countries in the world, under a baseline scenario and under future optimistic, business-as-usual, and pessimistic scenarios. Water stress is calculated as the ratio of total water consumption (domestic, industrial, irrigation, livestock), to available renewable water supplies (Hofste et al., 2019). More specifically, countries can be ranked according to their water stress score, which goes from 0, corresponding to low, to 5, equal to extremely high. Values associated with extremely high water-stress, which corresponds to scores between 4 and 5, means that more than 80% of the available water supply is withdrawn on average every year (Hofste et al., 2019). The first two columns of Table 4.5 show which countries are more water-stressed under the baseline scenario (World Resources Institute, 2019) – a representation of the current situation without anomalies – and under the business-as-usual projected scenario in 2040 (Luo et al., 2015). In both countries' rankings, the ten most water-stressed countries face extremely high water-stress, as their scores are all higher than 4. In general, higher scores mean that there is higher competition for water among users (Hofste et al., 2019). The baseline water stress indicates that nine out of the ten most affected countries are located in the Middle East and North Africa (MENA) region, all except Eritrea. The projected water stress ranking includes some countries that appears also in the baseline water stress list – such as Kuwait, Qatar, United Arab Emirates, Israel, Saudi Arabia – and which are supposed to worsen their water-stress condition.

According to the projections related to year 2040, some new countries will enter the top of the ranking, namely Bahrain, San Marino, Singapore, Palestine, and Oman.

Table 4.5. Water stress estimates and the risk of droughts

Countries Ranking (from the highest value to the lowest)	**Baseline Water Stress*** (0-low, 5-extremely high)	**Projected Water Stress in 2040**** (0-low, 5-extremely high)	**Drought Risk, period 2000-2014 ***** (0-low, 1-high)
1	Qatar (4.97)	Bahrain (5.00)	Moldova (0.82)
2	Lebanon (4.82)	Kuwait (5.00)	Ukraine (0.81)
3	Israel (4.82)	Qatar (5.00)	Bangladesh (0.79)
4	Iran (4.57)	San Marino (5.00)	India (0.76)
5	Jordan (4.56)	Singapore (5.00)	Serbia (0.75)
6	Libya (4.55)	United Arab Emirates (5.00)	Syria (0.74)
7	Kuwait (4.43)	Palestine (5.00)	Romania (0.73)
8	Saudi Arabia (4.35)	Israel (5.00)	Haiti (0.73)
9	Eritrea (4.33)	Saudi Arabia (4.99)	Morocco (0.73)
10	United Arab Emirates (4.26)	Oman (4.97)	Indonesia (0.73)

* Ratio of total water withdrawals, all sectors considered, to available renewable water supplies.
** Water stress projections based on a business-as-usual scenario.
*** Probability of occurrence of droughts and vulnerability of the assets and the population exposed (period 2000-2014).
Sources: *Baseline water stress* and *drought risk*, Aqueduct 3.0 Country Rankings dataset, World Resources Institute (2019); *Aqueduct projected water stress in 2040*, Luo et al. (2015), World Resources Institute.

The most water-stressed areas are typically more likely to be vulnerable to droughts, as the over-use of water resources can result in water crisis when some conditions, such as bad rainfall years, limit its availability. An indicator of drought risk per country is provided by the WRI, and it measures where droughts are likely to occur, the population and the assets exposed, and the vulnerability to adverse effects (Hofste et al., 2019, p.22). The WRI drought risk indicator, which considers the meteorological drought risk, but not the hydrological one, is assessed for the period 2000-2014 as a "combination of drought hazard (from an analysis of historical precipitation deficits), drought exposure (based on indicators of population and livestock densities, crop cover and water stress), and drought vulnerability (high level factors of social, economic and infrastructural indicators, collected at both the national and sub-national levels)" (Hofste et al., 2019, pp.22-23). The third column of Table 4.5 shows the ten countries that registered the highest scores, corresponding to an elevated drought risk. It is important to stress that for almost all the countries listed among the most water-stressed – under both the baseline and the projected future scenario in 2040 – data were not available for the drought risk indicator (World Resources Institute, 2019). These countries are: United Arab Emirates, Bahrain, Kuwait, Qatar, Oman, Saudi Arabia, Singapore, Jordan, Israel, Libya, San Marino. This is an important detail because most of the countries potentially exposed to a high drought risk are not included in the ranking due to lack of data. Nevertheless, the available data allow to identify some hotspots in which successful drought risk management plans are needed to cope with this threat, from Moldova (0.82), Ukraine (0.81), Serbia (0.75), Romania (0.73) in the European continent to Bangladesh (0.79), India (0.76), Indonesia (0.73) in Asia, and Syria (0.74), Haiti (0.73) and Morocco (0.73).

4.4 The crucial role of forests and biodiversity conservation

The good management of forests is a fundamental element in the climate change mitigation strategy. Indeed, forests are important carbon sinks, which help to regulate the climate, and when extreme weather events occur, such as heavy rainfalls, they prevent soil erosion and help to maintain soil quality. Moreover, forests are home the highest share of terrestrial biodiversity and they are suppliers of clean water, timber, rubber, fruits, and many other products used for food production. Furthermore, it is estimated that over 90% of people living in extreme poverty depends on forests for their livelihoods (FAO and UNEP, 2020).

The first column of Table 4.6, based on the Global Forest Resources Assessment (FAO, 2020e), shows which countries in 2020 have the largest area occupied by forests[45], expressed in million hectares. The Russian Federation is by far the country with the most extended forests, which amount to an area of 815 million hectares. Brazil, the country which hosts the largest part of the Amazon rainforest, follows with a forest area of 497 million hectares. The total forest area in 2020 amounts to 4,059 Mha, and more than 50% is located in five countries, namely the Russian Federation, Brazil, Canada, the United States of America, and China. Despite their recognized importance, a decreasing trend in forests area at world level has been registered since the 1990s[46] and the drivers are different, both natural and anthropogenic.

Global Forest Watch (GFW) is an initiative that offers important tools to monitor global forests; it was created by the World Resources Institute in collaboration with Google, USAID, the University of Maryland, and many other public and private partners. In fact, GFW provides data on tropical

[45] According to FAO, forest area comprises land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. Trees in agricultural production systems, such as fruit tree plantations, are excluded from this definition.

[46] See the decreasing trend in global forest area, from 1990s onwards, illustrated by the Global Forest Resources Assessment, available at https://fra-data.fao.org/WO/, accessed August 2020.

primary rainforest loss areas[47] by country, expressed in thousand hectares. As reported above, trees are critical in the fight against climate change through their role in the carbon sequestration process; however, on the contrary, huge carbon dioxide emissions are associated with their loss.

Table 4.6. Forest area, tree cover losses and agricultural land

Countries Ranking (from the highest value to the lowest)	**Forest Area 2020** (in Mha)	**Tropical Primary Rainforest Loss 2019** (by total area, '000 ha)	**Tree Cover Loss 2001-2019** (in Mha)	**Agricultural Land 2017** (in Mha)
1	Russian Federation (815)	Brazil (1,361)	Russia (64)	China (527)
2	Brazil (497)	Congo Dem. Rep. (475)	Brazil (56.5)	United States (405)
3	Canada (347)	Indonesia (324)	Canada (42.9)	Australia (371)
4	United States (310)	Bolivia (290)	United States (40.3)	Brazil (236)
5	China (220)	Peru (162)	Indonesia (26.8)	Kazakhstan (217)
6	Australia (134)	Malaysia (120)	Congo Dem. Rep. (14.6)	Russian Federation (216)
7	Congo Dem. Rep. (126)	Colombia (115)	China (9.92)	India (179)
8	Indonesia (92)	Laos (72)	Malaysia (8.12)	Saudi Arabia (173)
9	Peru (72)	Mexico (66)	Australia (6.11)	Argentina (148)
10	India (72)	Cambodia (63)	Paraguay (6.03)	Mongolia (111)

Sources: Global Forest Resources Assessment, FAO (2020e); Weisse and Goldman (2020); Global Forest Watch (2020); FAO (2019b).

The second column of Table 4.6, based on evidences illustrated by Weisse and Goldman (2020), provides a ranking of the countries which lost the highest area of primary rainforests in 2019, from the biggest loser to the smallest. At the top of the list there is Brazil, which lost 1,361,000 hectares of primary rainforest in 2019. The increase with respect to 2018 was modest, but the loss derived from deforestation for agriculture has particularly increased, and new worrying forest loss hotspots emerged within indigenous territories (Weisse and Goldman, 2020). The Democratic Republic of Congo is ranked second, with a loss of 475,000 hectares in the year considered. This value is the third highest on record for the country and most of the forest loss appears to be tied to shifting cultivation cycling. Other countries appearing on the top ten ranking are: Indonesia (324,000 ha), Bolivia (290,000 ha), Peru (162,000 ha), Malaysia (120,000 ha), Colombia (115,000 ha), Laos (72,000 ha),

[47] According to GFW's datasets, primary rainforests include mature natural humid tropical forest cover that has not been completely cleared and regrown in recent history. Their loss refers to the removal of trees in tropical areas due to human or natural causes, including fire, but it does not equal deforestation.

Mexico (66,000 ha) and Cambodia (63,000 ha). It is worth emphasizing that although Indonesia is the country that suffered the third highest rainforest loss in 2019, it decreased by 5% compared to 2018 and, more generally, the country has been experiencing a decreasing trend since 2016, as a consequence of national policies aimed to encourage the reduction of deforestation (Weisse and Goldman, 2020). Bolivia, ranked fourth, registered a record loss in 2019 due to fires, originated from a combination of climatic conditions and human activities, in the framework of a massive land clearing for large-scale agriculture (Weisse and Goldman, 2020).

Rainforests are essential for our planet, but it is important to have a whole picture of global tree cover loss values – thus not focused only on primary rainforests – to avoid the bias towards the countries that host forests in tropical areas. For this purpose, Global Forest Watch (2020) provides data to discover which countries suffered the greatest losses in tree cover[48] during the period 2001-2019. For this purpose, Landsat satellite images have been used to map annual tree cover loss at a 30 × 30 meter resolution, and data on tree cover in 2000 and 2010 were used as a baseline (data for the period 2011-2019 were produced with an updated methodology) (Global Forest Watch, 2020). The ranking in the third column of Table 4.6 classifies countries from the one with the largest loss – namely Russia, with 64 million hectares of tree cover lost during the period considered (2001-2019) – to the one with the smallest – Paraguay (6.03). Brazil places second with a loss of 56.5 million hectares, but also Canada and the United States suffered huge tree cover losses, equal to 42.9 and to 40.3 million hectares respectively. While forest areas are diminishing worldwide, the opposite trend can be observed for agricultural lands, which are increasing in terms of area occupied.[49] Indeed, agricultural expansion is considered as the main driver of deforestation and loss of forest biodiversity (FAO and UNEP, 2020). The last column of Table 4.6 ranks countries from the one with the largest agricultural land[50] in 2017, to the one with the smallest. China (527 million hectares), the United States (405 Mha) and Australia (371 Mha) appear at the top of the ranking, followed by Brazil (236 Mha) and Kazakhstan (217 Mha).

Forests, like oceans, provide home to many animal, plant, and insect species whose interconnections, fundamental for food production and for the human well-being, are highly vulnerable to the loss of

[48] According to GFW, tree cover includes all vegetation higher than 5 meters, which may take the form of natural forests or plantations. Tree cover loss is associated with the removal or mortality of tree cover attributable to a variety of factors, both natural and anthropogenic.

[49] See the increasing trend in Agricultural land area (1,000 ha) period 1961-2017 (FAO, 2019b). FAOSTAT Database, Inputs/Land Use domain available at http://www.fao.org/faostat/en/#data/RL, accessed August 2020.

[50] According to FAOSTAT, agricultural land comprises arable land, permanent crops and permanent meadows and pastures. Arable land is defined as land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years).

biodiversity[51]. Biodiversity is currently threatened by many factors, especially linked to human activities, such as unsustainable farming practices, urbanization, pollution, and habitat alteration. The International Union for Conservation of Nature (IUCN) regularly publishes the 'Red List of Threatened Species'[52], which is considered an important indicator of the state of biodiversity in the world. The list (IUCN, 2020) enounces the status of several species, divided by taxonomic group, considered at risk of extinction by a network of scientists and partner organizations. This list is an important and powerful tool for the future of biodiversity, as it allows to establish priorities for conservation measures.

Table 4.7. State of biodiversity

Countries Ranking (from the highest value to the lowest)	**Number of Threatened Animal Species* 2020**	**Number of Threatened Plant Species 2020**	**Biodiversity Index** 2016**
1	Mexico (769)	Madagascar (2,234)	Brazil (0.85)
2	Indonesia (701)	Ecuador (1,957)	Colombia (0.68)
3	Colombia (622)	Malaysia (1,059)	Indonesia (0.65)
4	Madagascar (571)	Mexico (837)	China (0.55)
5	India (561)	Tanzania (781)	Mexico (0.52)
6	China (490)	Brazil (734)	Peru (0.50)
7	United States (486)	Indonesia (673)	Australia (0.47)
8	Ecuador (471)	China (631)	India (0.46)
9	Australia (441)	Australia (607)	Ecuador (0.45)
10	Brazil (424)	Cameroon (591)	Venezuela (0.42)

* Animal species included are mammals, amphibians, fishes, reptiles, birds.
** The index considers birds, amphibians, mammals, reptiles, fish, and vascular plant species.
Sources: IUCN Red List of threatened species, IUCN (2020); Butler (2016), Mongabay.

The first column of Table 4.7 ranks countries according to their number of animal species classified by the IUCN Red List 2020 as threatened, putting the one with the highest number at the first place. At the top of the rank, Mexico appears as the country with the highest number of animal species

[51] According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), biodiversity is the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. Biodiversity loss consists in the reduction of any aspect of biological diversity (i.e., diversity at the genetic, species and ecosystem levels) is lost in a particular area through death (including extinction), destruction or manual removal. See https://ipbes.net/glossary/biodiversity and https://ipbes.net/glossary/biodiversity-loss, accessed July 2020.
[52] According to the IUCN Red List Categories, species threatened with extinction include critically endangered, endangered, and vulnerable species.

considered by the IUCN at risk of extinction (769), then Indonesia, Colombia, Madagascar, and others follow. However, the animal species are not the only ones at risk of extinction, indeed also many plant species are categorized as threatened. In 2020 Madagascar has the highest number of plants classified as threatened (2,234), followed by Ecuador (1,957), and Malaysia (1,059). The countries that appear on both rankings – and therefore which have a high risk of biodiversity loss – are Mexico, Indonesia, Madagascar, Ecuador, China, Brazil, and Australia.

The last column of Table 4.7 ranks the most biodiverse countries, as reported by Butler (2016), from the richest in biodiversity to the least rich. The biodiversity index constructed by Butler (2016) from various sources – including the IUCN – measures the species-richness per country, implying that a high biodiversity index is positive for the prevention of ecosystem losses and extinction of species. It is a weighted index accounting for the number of amphibians, birds, fish, mammals, reptiles' species, and vascular plants species. Each country is ranked according to its percentage of species in each group (for example the percentage of mammals' species present in Brazil) relative to the total number of species for each group (global number of mammals' species). The biodiversity index per country is the sum of the percentages recorded in all the six groups by each country. The ranking based on the biodiversity index suggests that most of biodiversity can be found in South America, in Mexico, in Asia, and Australia. Focusing on the top three positions, Brazil ranks first (0.85) thanks to the abundance of various terrestrial and aquatic ecosystems within its territory (Butler, 2016). Colombia, placed at second place (0.68) also can boast a variety of rich ecosystems; in particular, the country has more birds' species than any country in the world. Finally, Indonesia (0.65), placed at third place, holds the record for the highest number of mammals' species in the world.

4.5 Limits in international comparison analysis

An overview of some environmental risks that are currently challenging countries has been illustrated in this chapter, with the aim of identifying the areas that have been, or are predicted to be, most affected by the adverse impacts of an ever-changing environment. Some other indicators have been also integrated with these measures of risk, in order to provide a more comprehensive framework for the interpretation of the results. It is worth emphasizing that the field of environmental hazards is broad and heterogeneous, therefore it is not easy to summarize the level of risk tied to each country. For this reason, many premises are necessary, and the inherent limits of any analysis must be acknowledged. A classification of countries, based on their level of risk associated with each specific indicator, has been provided, but of course, many limits exist in the adoption of such approach. First of all, the aggregation of values by countries does not always provide a faithful reproduction of reality, because some specific regions, or areas, in some countries may face a high environmental risk, while the rest of the country may not. Moreover, data across countries often differ substantially in terms of data collection methodologies, and data accuracy, and therefore data for different countries are not perfectly comparable. The trade-off between data availability and data accuracy should also be considered, in fact data are expensive to obtain and not all countries have the same means to collect them. Data for some indicators – such as the *drought risk* – may not be available in some countries, thus making the corresponding ranking somehow distorted. A more integrated system of data collection would mitigate this problem, and at the same time could pave the way for integrated policies, that are needed to face a global challenge such as the current environmental crisis.

Many indicators of environmental risk mentioned in this chapter are based on predictions which are, by nature, uncertain. This is also an important detail to keep in mind when interpreting the results, because the level of uncertainty is really high and therefore caution is needed. Nevertheless, predictions are useful instruments that highlight where strong efforts are particularly needed. Focusing on the current state of international climate negotiations, the direction of the path taken from the Paris Agreement onwards is the right one, but along with the advantages of a universal participation in the pursuit of a global climate target, there are also several weaknesses. First of all, in the Agreement there are no clear targets that have to be met by countries, which instead are called to establish voluntarily their 'nationally determined contributions' aimed at reaching the long-term temperature and cutting of emissions goals. Therefore, the Agreement lacks the collective system of enforcement that would make countries accountable.

CHAPTER V.

VULNERABILITY TO ENVIRONMENTAL AND FOOD INSECURITY RISKS: AN OVERALL INDEX

The literature review and the exploration of the most relevant indicators – many of which are used to monitor progress towards the targets set by the 2030 Agenda – have thus far certainly made it possible to draw a rich, albeit fragmented, picture of the current state of vulnerability to environmental risks and food insecurity for many countries. What therefore becomes interesting to do at this point is to construct a measure of overall risk, an attempt already made elsewhere (Economist Intelligence Unit, 2019; Khrishnamurty et al., 2014), based on some of the indicators presented in the previous chapters. The purpose of this effort is that of identifying, to date, the main hotspots for food security, especially from the perspective of the impacts that this may suffer due to natural hazards and environmental constraints, both of which are expected to intensify in the years to come.

5.1 Intersecting the two risks

First of all, a number of developing countries have been selected in reason of their relevance to one or both of the risks to be measured, and of their location in the regions widely considered of most concern, namely Africa, Asia, Latin America and the Caribbean. Subsequently, a set of indicators to be used in the development of the overall index has been chosen among the wide array illustrated in previous chapters, and a couple of additional indicators have been integrated to enrich the designed framework. For indicators previously presented in units of measurement expressed in absolute terms (such as forest area in millions of hectares), in this context it was preferred to consider their relative values (forest area as a proportion of total land area) in order to facilitate comparability between countries and avoid bias towards the most populous countries or the largest in terms of area occupied. Clearly, this choice implies that in some cases the opposite bias may occur, namely that results for larger or more populous countries – depending on the indicator being considered – may be underestimated and high absolute values may hide behind modest relative values. Therefore, it is important to be aware of this limitation when interpreting the results, bearing in mind that the previous chapters partially compensate for this gap by providing an overview of the current state of vulnerability of countries that is often based on absolute figures.

5.2 Materials and methodology

The countries taken into consideration for the calculation of the index are Afghanistan, Bangladesh, Bolivia, Burundi, Cambodia, Central African Republic, Chad, Democratic Republic of the Congo, Ethiopia, Guatemala, Haiti, Indonesia, Kenya, Madagascar, Malawi, Mozambique, Nicaragua, Nigeria, Pakistan, Philippines, Republic of the Congo, Rwanda, Somalia, Sudan, Venezuela, Viet Nam, Yemen. The index, whose construction will be described in detail in the next lines, ranges from 0 to 100, where 100 corresponds to the highest level of overall risk, a measure which combines the current state of food (in)security with vulnerability to environmental risks. Indeed, these two risk typologies constitutes the macro categories to which the indicators belong and from which the index is constructed. A description of all the indicators used is provided in Table 5.1 (Risks to food security category) and Table 5.2 (Environmental risks category) below, which specify the sources of the data and the period to which they refer.

5.2.1 Risks to food security category

It has been widely argued that food security is a multidimensional concept, which encompasses the issues of availability, access, utilization, and stability. Consequently, indicators belonging to this category have been chosen to represent each of these dimensions (Table 5.1).

The availability dimension of the index consists of two indicators, one expressing the sufficiency of food supply at country level, and the other the demographic stress to which it is exposed. The former is the 'Average Dietary Energy Supply (DES) adequacy', a measure which shows the food calories supplied at country level (i.e., the DES) as a percentage of the Dietary Energy Requirement estimated for the country. The latter is the 'Population Growth Rate', introduced as a socioeconomic stressor to food availability, which indicates the average annual population change expressed in percentage terms. With regard to the access dimension, considering that in developing countries poverty is a major barrier to obtaining food and utilizing it properly, it has been decided to include a component of the multidimensional poverty index[53] that expresses the percentage of people classified as multidimensionally poor in the total population of each country. The dimension of utilization is closely linked to the notion of nutrition security, covering the issue of malnutrition and the quality of complementary services essential to the proper absorption of food. Thus, in this context, utilization is composed of two indicators, the first capturing the percentage of the population that has access to

[53] Poverty here is measured across three dimensions: health, education, standard of living. The three include a total of ten indicators (nutrition, child mortality, years of schooling, school attendance, cooking fuel, sanitation, drinking water, electricity, housing, assets). People who experience deprivation in at least one third of these weighted indicators fall into the category of multidimensionally poor (UNDP and OPHI, 2020).

basic drinking water, and the second reporting the percentage of children under the age of five who are stunted.

Table 5.1. Food insecurity risk indicators

Indicator	Year	Source
Average Dietary Energy Supply (% Average Dietary Energy Requirement)	2017-2019 (three-year average)	FAO*
Population growth (%)	2015-2020 (annual average for the period)	UNDESA
Multidimensional Poverty Headcount Ratio (% population)	2008-2018 (latest available year)	UNDP and OPHI**
Population using at least basic drinking water services (% population)	2017	WHO and UNICEF
Children affected by stunting (% children under five years of age)	2009-2019 (latest available year)	UNICEF, WHO, World Bank
Cereal import dependency ratio (%) (100 % highest dependence)	2015-2017 (three-year average)	FAO***
Arable land equipped for irrigation (% total arable land)	2015-2017 (three-year average)	FAO
Political stability and absence of violence/terrorism (score in units of a standard normal distribution, from -2.5 to +2.5, being +2.5 the highest level of stability)	2019	World Bank

* The primary source for this indicator (FAO, 2020a) provided no data for the Democratic Republic of the Congo and Burundi, thus the estimate of this value elaborated by the Economist Intelligence Unit (2019) was used for these countries.
** The collaboration between the United Nations Development Programme and the Oxford Poverty and Human development Index provided no estimations of multidimensional poverty for Venezuela and Somalia, thus two additional sources were integrated to fill the data gap. Specifically, for Venezuela it was considered the multidimensional poverty ratio as estimated by the Universidad Catòlica Andres Bello (2020) in its latest National Survey of Living Conditions. For Somalia, there were no available estimates of poverty from a multidimensional perspective, therefore the proportion of the population living below the international poverty line of US$1.90 per day (2011 PPP) in 2017 was considered (World Bank Group, 2019). This measure captures poverty only from the perspective of income and, ideally, should not be directly compared with multidimensional poverty estimates. However, the choice to use this indicator to fill the data gap provides a measure that is nonetheless reliable and, above all, avoids the exclusion of Somalia from the analysis.
*** FAO (2020a) did not directly provide the value of this indicator for Somalia, Burundi, and Democratic Republic of the Congo; therefore, the author has computed it starting from FAO (2020c, 2020d) data on production, import and export of cereals in the three years under examination. In fact, the Cereals import dependency ratio results from: (cereal import - cereal export)/ (cereal production + cereal import – cereal export) *100.

Finally, it is well known that stability ensures the fulfillment of availability, access, and utilization over time, and is probably the most multifaceted dimension. For this reason, it was decided to consider three indicators as being part of this dimension, specifically relating to dependence on cereals imports, the extent of irrigation infrastructure and political stability. The first can signal an excessive reliance on international markets to satisfy the needs of domestic consumers, and this represents a vulnerability factor since, from a broader perspective, foodstuff prices and quantities on international markets can be extremely volatile and severely impact the food security of a country that is not food self-sufficient. The second expresses the percentage of arable land that is equipped for irrigation, a process that contributes to increasing yields, but especially to safeguarding them from undesirable effects that they may suffer due to suboptimal climatic conditions. Thinking about the extreme vulnerability that characterizes rainfed agriculture – totally dependent on rainfall patterns – well exemplifies the importance of irrigation systems. Finally, a country's political stability and the existence of conflicts is another crucial element for food security, such that the United Nations formally recognized the link between the two in a 2018 resolution in which, among other things, the use of hunger as a weapon of war was banned (United Nations, 2018).

5.2.2 Environmental risks category

Agriculture is by nature closely linked to climatic conditions and strongly depends on natural resources, with a fundamental role played by the two non-reproducible resources water and land. Environmental risks – understood here as the impact of extreme climatic and natural events, but also as threats to the availability and quality of the two key resources land and water – can have a heavy impact on societies and economies, especially on those already unstable and with modest means to cope with emergencies. With these premises, it is quite evident that the risks posed by the natural environment are a serious threat to food security. The indicators belonging to this category have, therefore, been chosen to depict the current state of vulnerability of the countries analyzed. They take into account the exposure to extreme weather events, registered in the past, how much it is expected to be so in the coming decades, but also factors such as soil quality, forest wealth and the productivity of cereals (Table 5.2).

In particular, the total number of deaths caused by natural disasters over the 20-year period 2000-2020 was considered as an indicator of exposure to natural hazards. Data provided by the EMDAT database (EMDAT, 2021), which reports damage from all types of natural disasters, were filtered to retain those relevant to the purpose of the index. Therefore, disasters of geophysical nature have been excluded (such as earthquakes, volcanic eruptions), while floods, droughts, storms, epidemics, extreme temperatures, insect infestations, landslides, and wildfires have been incorporated.

With respect to the risk of exposure to extreme events in the future, estimates of the population that is projected to be affected by riverine as well as coastal flooding have been considered, with the latter being closely linked to the threat posed by sea level rise. These two indicators are part of those already introduced in the chapter on environmental risk indicators which were expressed in absolute terms (millions of people), and which are instead reported here as a percentage of the total population. Focusing then on the risk of water stress, which results from the ratio of water withdrawals to available renewable water supplies, the indicator 'Projected water stress in 2040' was included, a prediction based on a business as usual scenario.

With reference to the non-reproducibility of land, soil quality is extremely important because a fertile and nutrient-rich soil ensures the productivity and quality of crops. For this reason, land that does not possess these qualities is classified as degraded and constitutes a limiting factor for food production that could be further exacerbated, and which requires restoration measures. Therefore, an indicator expressing the proportion of land that is classified as degraded has been included in the index calculation. In contrast, the extension of forest areas, often threatened by agricultural expansion, contributes positively to the functioning of ecosystems and the conservation of natural resources and biodiversity, without overlooking the fact that trees also play the important role of carbon sinks. Accordingly, the indicator on the percentage of land occupied by forests has been considered as a relevant measure of vulnerability reduction.

Table 5.2. Environmental risk indicators

Indicator	Year	Source
Deaths from natural disasters (number)	2000-2020 (entire period)	EMDAT
Population annually affected by riverine flooding (% total population)	2030	WRI
Population exposed to an average annual coastal flood (% population)	2050	Climate Central
Projected water stress (score from 0 to 5, being 5 the highest stress level)	2040	WRI
Degraded land (% total land area)	2015	United Nations*
Forest area (% total land area)	2020	FAO
Cereals yields (hg/ha)	2019	FAO

* The primary source for this indicator (United Nations, 2020a) provided no data for Haiti, Yemen, Nicaragua, and Mozambique, thus an estimate of this value elaborated by the Economist Intelligence Unit (2019) was used for these countries.

Finally, considering the extreme sensitivity of agricultural yields to environmental factors, productivity can be heavily affected by environmental risks – especially if these are not offset by technological innovation – and compromise total production. Therefore, the productivity of cereals, expressed in hectograms per hectare, has been taken into consideration, starting from the assumption that countries which currently record the lowest yields per hectare are those that are already in suboptimal conditions and are thus more vulnerable. On this issue, however, it is good to emphasize that, on the contrary, very high levels of productivity have reduced margins for further improvement.

5.2.3 Methodology

In order to obtain an aggregate index from a set of indicators expressed in different units and on different scales, it was necessary to proceed in stages, starting first of all with the normalization of values. Specifically, it was decided to opt for a min-max normalization, which made it possible, for each indicator, to transform the values recorded by countries into scores on a scale between 0 and 1, where the minimum value was transformed into 0, and the maximum – associated with the highest level of risk – into 1. Then, considering the overall index range was decided to be between 0 and 100, the final normalized score for each indicator (on a scale 0-1) was multiplied by 100.
Given that not all of the indicators chosen are positively correlated with the overall risk that the index intends to capture, normalization of the values was carried out following two different calculations depending on the positive or negative correlation with the risk. For indicators that are positively correlated with risk, i.e., whose higher values signal greater susceptibility to risk, the normalized value of each indicator (the score) was obtained using the following calculation:

$$x_n = (x-x_{(min)}) / (x_{(max)}-x_{(min)}) *100$$

where x is the raw value of the indicator to be normalized, x(min) is the minimum value recorded for that indicator among the countries considered, and x(max) is the maximum.
On the other hand, for indicators whose higher values indicate lower vulnerability to risk (average DES adequacy, population using at least basic drinking water services, arable land equipped for irrigation, forest area, political stability and absence of violence/terrorism, cereals yield), i.e., which have a negative correlation with risk, the calculation used was:

$$x_n = 100- ((x-x_{(min)}) / (x_{(max)}-x_{(min)}) *100.$$

Once all values, for all indicators, were normalized, the calculation of the score for each of the two categories (‘Risks to food security’ and ‘Environmental Risks’) was carried out. The category score, on a scale from 0 to 100, was obtained by calculating the weighted average of the scores of the respective indicators, which were given different weights (see Table A1 in the Appendix). Finally, it was possible to compute the overall index score by calculating the weighted average of the scores of the two categories (greater weight was given to the ‘Risks to food security’ category, 55 per cent).

5.3 Results

The process for calculating the overall index of vulnerability – to environmental and food security risks – allowed to obtain a score on a scale from 0 to 100 for each country analyzed. Keeping in mind that higher values correspond to higher levels of risk, it was possible to draw up a ranking and identify the most endangered countries and regions. The complete ranking based on the overall index score is presented in Table A2 (see Appendix). Two further rankings, based on category scores, are illustrated in Table A3 and A4 (Appendix).

Focusing on the ten countries with the highest overall scores (Table 5.3), it can be seen that Somalia leads the ranking with a score of 72, leaving Chad almost eight points behind (64.3). Then, Burundi, Yemen, Mozambique, Central African Republic, Afghanistan, Ethiopia, Haiti, and Democratic Republic of the Congo follow. Somalia registers scores well above average in both categories, placing third in the Risks to food security category (Table 5.4), and at the top of that of Environmental risks (Table 5.5). In particular, the country records the worst result among the countries analyzed in the average dietary energy supply adequacy, the projections of the population affected by riverine flooding, and cereals productivity. In addition, very high risk scores in demographic stress (91), poverty (79.7), access to clean water (77.6), dependence on cereals imports (84.9), political stability (86.6), forest area (86.6), but especially in the mortality related to natural disasters (93.2), outlines the most critical risk drivers for the country.

Table 5.3. The ten most vulnerable countries according to the index

RANK	COUNTRY	REGION	SCORE
1	Somalia	Sub-Saharan Africa	72.0
2	Chad	Sub-Saharan Africa	64.3
3	Burundi	Sub-Saharan Africa	59.2
4	Yemen	Middle East	57.4
5	Mozambique	Sub-Saharan Africa	57.2
6	Central African Republic	Sub-Saharan Africa	56.7
7	Afghanistan	South Asia	56.6
8	Ethiopia	Sub-Saharan Africa	55.1
9	Haiti	Latin America and Caribbean	53.8
10	Democratic Rep. of the Congo	Sub-Saharan Africa	53.8

Seven of the ten most at risk countries are located in Sub-Saharan Africa, the others being Yemen (Middle East), Afghanistan (South Asia), and Haiti (Latin America and the Caribbean). All the African countries in Table 5.3 also register the highest scores in the Risks to food security category (Table 5.4), but Chad is the only one, besides Somalia, which also appears among the countries most at environmental risk (Table 5.5).

More generally, the risk drivers that are most prevalent among these African countries are insufficient food supply (with DES adequacy rates below 100 for six of them, all except Ethiopia), demographic stress, poverty, lack of irrigation facilities, and little access to safe drinking water. Furthermore, all of them (except, again, Ethiopia) are among the ten countries with the lowest cereals' productivity, hence registering the highest scores in this indicator.

Table 5.4. The ten countries most vulnerable to the risk of food insecurity

RANK	COUNTRY	REGION	SCORE
1	Central African Republic	Sub-Saharan Africa	80.4
2	Chad	Sub-Saharan Africa	78.2
3	Somalia	Sub-Saharan Africa	77.3
4	Burundi	Sub-Saharan Africa	75.7
5	Democratic Rep. of the Congo	Sub-Saharan Africa	75.5
6	Mozambique	Sub-Saharan Africa	72.3
7	Ethiopia	Sub-Saharan Africa	72.0
8	Yemen	Middle East	64.6
9	Madagascar	Sub-Saharan Africa	63.9
10	Afghanistan	South Asia	62.3

Instead, Yemen's main weaknesses – which are associated with the maximum score of 100 – derive from the political instability and violence inflicted by the ongoing conflict, the heavy dependence on imports for the domestic supply of cereals, the projected level of water stress, and the almost lack of forested areas on its territory (about 1%). Afghanistan, similarly, suffers particularly from strong political instability caused by many years of conflict, and a modest area of forest cover (with scores in these two indicators lower only than those of Yemen). Moreover, the country ranks fifth in the environmental risk category, due to the predicted risk of riverine flooding (fourth with a score of 43.7), the predicted water stress (third with a score of 86.9) and, as mentioned above, the low area occupied by forests. Finally, the main threats Haiti encounters derive not so much from its exposure to food insecurity risk per se – although it ranks fifth in dietary energy supply adequacy and cereals import dependence – but rather from its exposure to environmental risks, recording the third highest score in this category (Table 5.5). In fact, Haiti, among the countries analyzed, is the third most affected by natural disasters in terms of human lives lost, the fourth most at risk of water stress in the immediate future, and the fourth in terms of the percentage of degraded land. In addition, it records a very high risk score (91.6) in cereal productivity, which is among the lowest analyzed, slightly higher only than that registered by some African countries (Somalia, Sudan, Mozambique, Central African Republic, Democratic Republic of the Congo, Chad, Republic of the Congo) and by Yemen.

Table 5.5. The ten countries most vulnerable to environmental risks

RANK	COUNTRY	REGION	SCORE
1	Somalia	Sub-Saharan Africa	65.5
2	Bangladesh	South Asia	60.2
3	Haiti	Latin America and Caribbean	54.9
4	Philippines	Southeast Asia	51.8
5	Afghanistan	South Asia	49.6
6	Yemen	Middle East	48.6
7	Chad	Sub-Saharan Africa	47.2
8	Kenya	Sub-Saharan Africa	44.4
9	Pakistan	South Asia	44.2
10	Sudan	Sub-Saharan Africa	44.0

An overall analysis of the results at regional level shows that Asian countries are particularly exposed to environmental risks, with five countries – out of a total of nine analyzed – in the top ten positions (Table 5.5). Of these, only Afghanistan and Yemen appear among the ten most at-risk countries according to the overall index (Table 5.3), as they also score very high in the food risk category (Table 5.4), proving that food security in these countries is further threatened by environmental risks. The other three Asian countries (Bangladesh, Pakistan, and the Philippines), on the other hand, despite their high scores in the Environmental risks category, do not appear among the most at-risk countries according to the overall index, as they register very low scores for the risk of food insecurity (25.7, 38 and 24.7 respectively). In particular, of all the countries analyzed, Bangladesh is the country with the highest proportion of degraded land (65%) and the second country expected to be most affected by both riverine and coastal flooding (behind Somalia in the former case, and Vietnam in the latter). Pakistan is projected to be the second most water-stressed country in 2040 (behind Yemen), and records a high score (94) in the indicator on forest area as a percentage of total land, as this proportion is very low (4.8%). Finally, the Philippines had the highest number of victims from natural disasters in the last two decades (25,097), and records scores for projected water stress (63.5) and percentage of degraded land (55) that are well above the average score for these indicators (29.1 and 31.7 respectively).

Still from a regional perspective, the results show that African countries are the most food-insecure, placing all in the top 17 positions in this category, with only Yemen, Afghanistan and Haiti breaking their dominance at the top of the ranking.

In conclusion, intersecting the two categories shows that countries whose food security is already severely compromised, or precarious, are also those that suffer the worst impact of environmental risks because the latter exacerbate the existing conditions in affected countries. This explains the widespread presence of Sub-Saharan African countries in the upper part of the overall ranking. In fact, it is widely argued that environmental risks, linked to climate change, are expected to disproportionately impact countries, communities and households that are already food insecure – such as those in sub-Saharan Africa – further deteriorating their conditions (Krishnamurthy et al., 2014; Schmidhuber and Tubiello, 2007). Such evidence is consistent with the findings of Khrishnamurty et al. (2014), namely that for assessing the vulnerability of a country's food security to the effects of climate change, exposure is not as crucial as the capacity to cope with risk and adapt, capacity that is reasonably assumed to be reduced in countries which are already struggling with food insecurity.

5.4. Limitations of the analysis

Although the analysis conducted provides interesting insights into the subject studied, that of food insecurity risk and environmental risk, it is also characterized by important limitations that should be highlighted. First of all, the use of data on a national scale often hides intra-country heterogeneities, hence a country considered at medium risk could instead include highly vulnerable areas. Then, the choice of indicators to be included in the calculation, and countries to be analyzed, encountered critical issues of various kinds. The first was undoubtedly that of choosing a reasonable number of relevant indicators and finding a sufficiently wide availability of data. Some indicators that would have been very significant (such as the prevalence of severe food insecurity in the population, the drought risk, direct economic losses attributed to disasters relative to GDP, etc.) were excluded precisely because of the lack of data for certain countries. The selection of countries, similarly, was constrained by the availability of data. Then, as mentioned at the beginning of this chapter, the use of values expressed in relative terms may represent a limitation. In fact, indicators expressed in relative terms – widely preferred in the calculation of the index – favor comparability between countries, but do not highlight the magnitude of the absolute values they express, which in some cases could be very large.

Among the environmental risks, the risk of exposure to coastal floods has been included because such natural hazards, combined with the phenomenon of sea level rise, are a threat of huge scale that is leading to rethinking the human occupation of coastal areas. However, there are countries that because of their geographical and natural characteristics are landlocked and are therefore not exposed to this phenomenon. This implies that in the assignment of a risk score correlated to this indicator these countries scored 0, but merely due to their geographical position.

Furthermore, a general observation that is worth pointing out is that the selected countries are all particularly susceptible to environmental risks. Therefore, countries in more backward positions in such category are not to be considered exempt from environmental risks, but instead less vulnerable to the types of risk covered by the analysis than countries occupying higher positions.

Finally, there are some aspects that were not covered in the analysis conducted, but which could constitute important elements in the development of a higher quality index. For instance, indicators on the capacity of countries to implement measures for adaptation to environmental risks, as well as mitigation, and indicators on the existence of support mechanisms for farmers and communities in need of assistance.

CONCLUSION

Food systems are closely connected to the natural environment in which they are embedded and on which they depend for their activities, first and foremost the production of food, but also the other activities that follow in the food supply chain. This interconnection was illustrated throughout the dissertation, first by highlighting what directions have been recently taken at the policy level to make food systems more sustainable (e.g., the European ‘Farm to fork strategy’), moreover emphasizing the importance of the convergence of all the SDGs to achieve food security in all its dimensions. The call for more sustainable food systems arises exactly because, as was noted in Chapter 2, they contribute significantly to exacerbating the ongoing environmental crisis, the effects of which are dangerous to the activities of food systems themselves, through the sudden occurrence of extreme events, deterioration and increasing scarcity of natural resources, and the emergence of new pests and diseases. It is precisely this exposure to environmental hazards that raises food security concerns, especially for the most vulnerable, who are especially those with little ability to adapt to and recover from such shocks. For these reasons, pursuing the *Zero Hunger* goal of the 2030 Agenda requires increasing the resilience against environmental shocks of communities, farmers, and food systems as a whole, and WFP's contribution in this respect is considerable, with projects such as the FFA and the R4 Rural Resilience Initiative.

Then, the extensive research on indicators relevant to the topic of interest illustrated in Chapters 3 and 4 has brought to light the most recent trends in food security and susceptibility to environmental risks at the national level, based on the available data made public by the most authoritative statistical sources. The evidences that emerged, although reporting a fragmented picture, served as a background to develop an overall risk measure able to encompass both food insecurity and vulnerability to environmental hazards. The results obtained from the development of the overall risk index presented in Chapter 5, despite this being a tool with evident limitations, seem to corroborate the existence of an interconnection between food insecurity and environmental risks. More specifically, that countries affected by high degrees of food insecurity are also those that suffer the heaviest impacts of environmental risks, which act as an additional stressor in already critical situations. This result is consistent with some found in other research and analysis. For example, the GFSI 2019 – the results of which were discussed in section 3.1 – also found that the most food insecure countries according to the Baseline index (which accounted for the food security dimensions affordability, availability, quality and safety) worsened their scores with the introduction of the Natural Resources and Resilience category, and were confirmed as the most vulnerable countries in the Adjusted index (which included the National Resources and Resilience category in addition to the three categories covered by the Baseline index).

Also, Krishnamurthy et al. (2014) constructed a *Hunger and Climate Vulnerability Index* with the aim of assessing the vulnerability of food security to climate risk at national level. Their analysis, using the percentage of undernourishment as a proxy for hunger and investigating its correlation with each of the three categories determining vulnerability to climate events (exposure, sensitivity, adaptive capacity), revealed that undernourishment is strongly correlated with adaptive capacity (r = - 0.791), moderately correlated with sensitivity (r = 0.623), and to a lesser extent correlated with exposure (r = 0.511). Based on their findings, it can therefore be concluded that the capacity to adapt to the impacts of climate change and related risks (such as the occurrence of extreme natural events) plays a central role. However, this capacity is not uniformly distributed, being dependent on many factors, including economic and social development, the quality of institutions, and technology, which are arguably deficient in the countries most affected by food insecurity. This also reinforces the assumption that the most food insecure countries are the most vulnerable to climate risks.

Certainly, the index developed here is constrained by the kind of data that are publicly available at the present time, which are fragmented and not always reflect the most recent developments, considering the dynamic nature of the values they are supposed to report. However, it allowed to find concrete evidence of the disproportionate effect of environmental risks on the food insecure, a crucial element to be considered in order to seriously address the problem of food insecurity.

Further efforts are needed to expand data availability especially for developing countries, where data are often lacking or out of date. Wider availability of data and greater comparability among them – often hampered by differing methodology, varying levels of accuracy, and varying data quality across countries – would facilitate the development of more accurate and comprehensive risk measures. Moreover, the present and future efforts of international cooperation must be aimed at further strengthening the support to the countries most vulnerable to climate risks, which are not food self-sufficient and have high levels of food insecurity. Such support, which is essentially what the Sendai Framework calls for, should be directed at pursuing innovations in agriculture, adopting sustainable practices that can help reduce vulnerability, and increasing resilience and preparedness to shocks.

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APPENDIX

Table A 1. Weights attributed to categories and indicators in the construction of the index

Indicators	**Percentage weight**	
RISKS TO FOOD SECURITY		*55*
Average DES (% Average Dietary Energy Requirement)	15.4	
Population growth (%)	5.1	
Multidimensional Poverty Headcount Ratio (% population)	25.6	
Population using at least basic drinking water services (% population)	12.8	
Children affected by stunting (% children under five years of age)	12.8	
Cereal import dependency ratio (%)	7.7	
Arable land equipped for irrigation (% total arable land)	10.3	
Political stability and absence of violence/terrorism (score from -2.5 to +2.5)	10.3	
ENVIRONMENTAL RISKS		*45*
Deaths from natural disasters (number)	13.7	
Population annually affected by riverine flooding (% total population)	11.8	
Population exposed to an average annual coastal flood (% population)	11.8	
Projected water stress (score from 0 to 5)	11.8	
Degraded land (% total land area)	17.6	
Forest area (% total land area)	17.6	
Cereals yields (hg/ha)	15.7	
Total		**100**

Table A 2. The ranking of countries by overall index score

RANK	COUNTRY	REGION	SCORE
1	Somalia	Sub-Saharan Africa	72.0
2	Chad	Sub-Saharan Africa	64.3
3	Burundi	Sub-Saharan Africa	59.2
4	Yemen	Middle East	57.4
5	Mozambique	Sub-Saharan Africa	57.2
6	Central African Republic	Sub-Saharan Africa	56.7
7	Afghanistan	South Asia	56.6
8	Ethiopia	Sub-Saharan Africa	55.1
9	Haiti	Latin America and Caribbean	53.8
10	Democratic Rep. of the Congo	Sub-Saharan Africa	53.8
11	Sudan	Sub-Saharan Africa	51.9
12	Kenya	Sub-Saharan Africa	50.2
13	Nigeria	Sub-Saharan Africa	48.6
14	Madagascar	Sub-Saharan Africa	48.6
15	Rwanda	Sub-Saharan Africa	47.9
16	Malawi	Sub-Saharan Africa	42.9
17	Bangladesh	South Asia	41.2
18	Pakistan	South Asia	40.8
19	Philippines	Southeast Asia	36.9
20	Cambodia	Southeast Asia	35.2
21	Republic of the Congo	Sub-Saharan Africa	35.0
22	Guatemala	Latin America and Caribbean	34.3
23	Venezuela	Latin America and Caribbean	33.3
24	Nicaragua	Latin America and Caribbean	29.0
25	Bolivia	Latin America and Caribbean	27.4
26	Indonesia	Southeast Asia	25.4
27	Viet Nam	Southeast Asia	20.2

Table A 3. The ranking of countries by Risks to food security category score

RANK	COUNTRY	REGION	SCORE
1	Central African Republic	Sub-Saharan Africa	80.4
2	Chad	Sub-Saharan Africa	78.2
3	Somalia	Sub-Saharan Africa	77.3
4	Burundi	Sub-Saharan Africa	75.7
5	Democratic Rep. of the Congo	Sub-Saharan Africa	75.5
6	Mozambique	Sub-Saharan Africa	72.3
7	Ethiopia	Sub-Saharan Africa	72.0
8	Yemen	Middle East	64.6
9	Madagascar	Sub-Saharan Africa	63.9
10	Afghanistan	South Asia	62.3
11	Rwanda	Sub-Saharan Africa	59.4
12	Sudan	Sub-Saharan Africa	58.3
13	Kenya	Sub-Saharan Africa	55.0
14	Nigeria	Sub-Saharan Africa	53.9
15	Haiti	Latin America and Caribbean	53.0
16	Malawi	Sub-Saharan Africa	52.2
17	Republic of the Congo	Sub-Saharan Africa	47.8
18	Venezuela	Latin America and Caribbean	46.3
19	Cambodia	Southeast Asia	40.1
20	Pakistan	South Asia	38.0
21	Guatemala	Latin America and Caribbean	37.4
22	Nicaragua	Latin America and Caribbean	31.5
23	Bolivia	Latin America and Caribbean	30.9
24	Bangladesh	South Asia	25.7
25	Philippines	Southeast Asia	24.7
26	Indonesia	Southeast Asia	22.2
27	Viet Nam	Southeast Asia	9.0

Table A 4. The ranking of countries by Environmental risks category score

RANK	COUNTRY	REGION	SCORE
1	Somalia	Sub-Saharan Africa	65.5
2	Bangladesh	South Asia	60.2
3	Haiti	Latin America and Caribbean	54.9
4	Philippines	Southeast Asia	51.8
5	Afghanistan	South Asia	49.6
6	Yemen	Middle East	48.6
7	Chad	Sub-Saharan Africa	47.2
8	Kenya	Sub-Saharan Africa	44.4
9	Pakistan	South Asia	44.2
10	Sudan	Sub-Saharan Africa	44.0
11	Nigeria	Sub-Saharan Africa	42.1
12	Burundi	Sub-Saharan Africa	39.1
13	Mozambique	Sub-Saharan Africa	38.8
14	Ethiopia	Sub-Saharan Africa	34.4
15	Rwanda	Sub-Saharan Africa	33.8
16	Viet Nam	Southeast Asia	33.8
17	Malawi	Sub-Saharan Africa	31.5
18	Guatemala	Latin America and Caribbean	30.6
19	Madagascar	Sub-Saharan Africa	29.9
20	Indonesia	Southeast Asia	29.2
21	Cambodia	Southeast Asia	29.2
22	Central African Republic	Sub-Saharan Africa	27.6
23	Democratic Rep. of the Congo	Sub-Saharan Africa	27.3
24	Nicaragua	Latin America and Caribbean	25.9
25	Bolivia	Latin America and Caribbean	23.1
26	Republic of the Congo	Sub-Saharan Africa	19.4
27	Venezuela	Latin America and Caribbean	17.4