Chapter 1

Big Changes in Global Food Security and the Issue of Development: Challenges and Hopes

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1.1 Introduction

Food security and safety are not recent issues on a human scale (Birlouez, 2019, Litzenburger, 2016). They have been the subject of relentless efforts since humans first became aware of the time scale in which life occurs. Control of these issues has developed in parallel with scientific and technological knowledge. A tipping point can be located around the middle of the 19th century, with the appearance of the first combustion engines that led to the increase of agricultural productivity and the transportation of products, and with the Pastorian discoveries that laid the scientific foundations of food preservation.

Five pillars of food security - in the broadest sense - have been chronologically accepted and formalized over the last sixty years: the availability of food in sufficient quantity, the possibility of economic access to resources, the conformity of sanitary quality and composition of ingredients and the plate, the stability of supply in the short and medium term, and more recently the long-term sustainability of the system in order to guarantee intergenerational solidarity (Akram-Lodhi, 2009). These dimensions are of major importance in order to contribute to the stability of our societies. This article reviews some of the issues related to food security and safety, and avenues to ensure their continuity. More specific aspects related to food security will be highlighted.

2. Food security issues

Paradoxically, the major world conflicts were catalysts for population growth (Figure 1). It was particularly after the Second World War that the human population showed a strong relative expansion. The phenomenon was most pronounced in Asia, then later in Africa. This continent is currently the only one to present an exponential increase in population, compensating for the decreases observed elsewhere. The world population growth has been linear for the last 50 years, at a rate of nearly 70 million people per year.

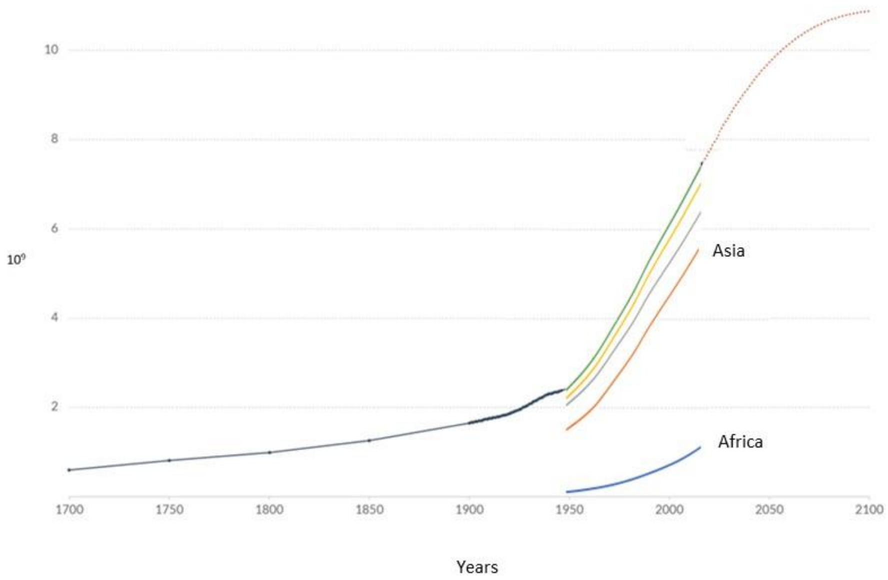

Figure 1. *Three-century evolution of the world's population, broken down cumulatively by continent from 1950 to the present-day, and projected to the end of the century (from Our World in Data, 2021 and United Nations, 2019).*

Improved agri-food practices and increased agricultural production have undoubtedly contributed to these demographic shifts. For example, the share of the world's population fed by agricultural practices using synthetic fertilizers has risen from virtually nothing to nearly 50% in 60 years (Erisman et al., 2008).

The preservation of food security is currently under threat, and humanity is facing challenges, which Hajkowicz (2015) has termed "mega-trends," or large-scale conjunctural "shifts". These shifts are all anthropogenic in origin and are likely to force humanity to reconsider how it will need to feed itself in future decades. The "demographic tide" movement mentioned above is one of these challenges.

The gradual increase in the earth's temperature is another, as it threatens the very foundations of agricultural productivity. The NCEI (National Centers for Environmental Information) of NOAA (National Oceanic and Atmospheric Administration of the Department of Commerce in the USA) publishes every year the map of thermal anomalies recorded on the planet. In the last three years alone (Figure 2), most regions of the globe have shown anomalous thermal averages compared to recent decades. Global warming will have consequences on the capacity of human organizations to ensure stable agricultural production. Thus, in most regions of the world, we must expect the emergence of extreme climatic events, such as torrential rains or scorching temperatures, which are not easily predictable in the short term. The management of water, whether to store it or to obtain it, will therefore become a major issue of food security.

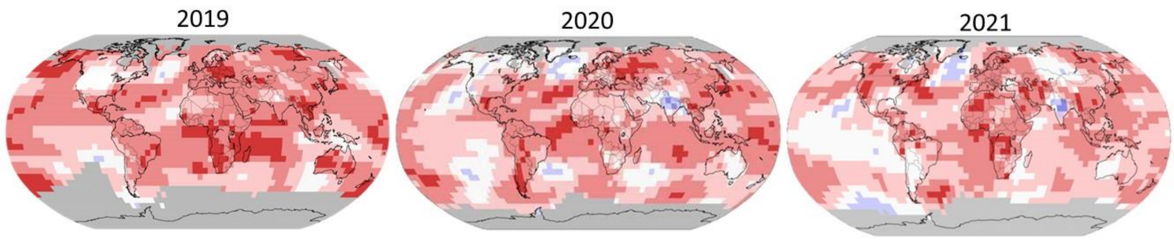

Figure 2. *Percentiles of thermal anomalies (positive in red, negative in blue) recorded over land in the last three years (from National Center for Environmental Information, 2019, 2020, 2021).*

Urbanization and migration to cities reflect another trend that has been sustained for several decades. It profoundly modifies the relationship between human beings and the land and causes an evolution from global, climatic food insecurity to a more economic form. Indeed, urban populations, although maintaining close social relations with peri-urban or rural areas, are more dependent on the availability of and access to imported food. Notwithstanding their density, they cannot reasonably rely on significant production of resources from the cities themselves. The vast majority of urban land is not suitable for agriculture, due to the presence of roads and buildings. Even attempts to develop green roofs are hampered by the existence of artificial soil that is not deep enough to regulate water and nutrient cycling as is the case in natural soils. As a general rule, the relative yields of such agriculture can only be low. Urban populations are thus dependent on rural production by road for their food, but even more so on imports through international trade routes, which are often facilitated by the presence of large cities near port areas, whether by river or sea.

In urban areas, the privileged access to imported food resources has several consequences. On the one hand, people are no longer forced to cultivate the land, and on the other hand, they have easier access to highly refined foods such as oils, simple carbohydrates, or intensively produced meats. The latter are themselves often richer in fat - and therefore less rich in animal protein - because of the speed with which the animals grow. The consequences of access to these resources result in an increasing incidence of obesity when the income linked to the social class to which the individual belongs allows him to make these choices. Malnutrition through overeating is another major current trend.

Moreover, the easier access to imported food reflects another phenomenon that has become more widespread since World War II, namely the speed and fluidity with which food travels along distribution channels. These two characteristics reflect a unified world in terms of transportation and communication, and also facilitate the mechanisms of genetic introgression within ecological niches, and consequently the transfer of pathogens, with the associated epidemic risks.

Paradoxically, despite these threats, the average life expectancy of the population is continually increasing, and although the natural age pyramid is normally presented in pyramidal form, as its name indicates, it shows a strong relative erosion of the proportion of the young population (Figure 3). In some countries, such as Japan, there has also been a marked reduction in the birth rate (Matsuda, 2020). Some pyramids may therefore evolve into the shape of an inverted teardrop, evoking the image of a hot air balloon rising towards a glass ceiling. Even if some states try to fight against birth rate decreases by promoting immigration or by adopting family protection reforms, the global evolution of the age pyramid will have consequences on food security criteria. As people age, and particularly as they pass a threshold in older age, nutritional needs change (Rusu et al. 2020). Energy requirements - mainly related to the consumption of fats and carbohydrates - decrease, while the need for high biological value proteins, which can help kidney function, increases, as well as the need for minerals and vitamins, and the importance of fiber and antioxidant factors. The modification of the age pyramid profile is thus gradually changing the composition of the plate. This is perhaps one of the elements that explain the current interest in organic or biological production.

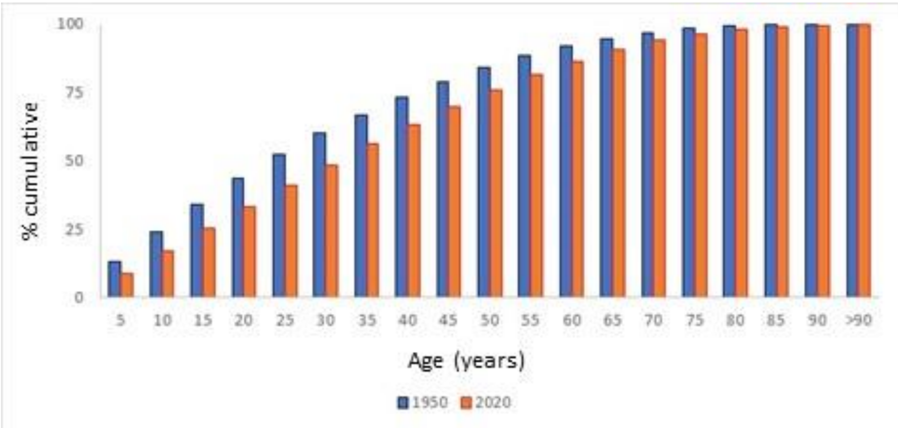

Figure 3. *Comparison of cumulative percentage of the world's population by age category, 1950-2020 (calculated from United Nations, 2019)*

Taken together, these societal changes go hand in hand with a temporal contraction of food supply processes, but also with a form of spatial, economic and cognitive dilation of the steps in these processes. Indeed, with the development of means of transport, food travels further, which requires a multiplication of economic intermediaries, atomizes the distribution of added values - whether aggregated or not within these intermediaries - and this dilation also results in a feeling of insecurity as to the origin of the food. The latter is responsible for anxiety, and even chaos, when the already fragile confidence of the consumer in what he eats is called into question (Bricas, 2003). Examples such as the mad cow crisis or the recurrent discovery of undesirable residues in consumer products remain in the collective memory or are part of people's daily lives. This anxiety is rarely totally justified when compared to objective facts, but it is part of our human nature. However, the points of attention that mobilize societies vary according to culture. Thus, the countries of the European Union are particularly demanding of traceability and transparency within the food chain. Latin American countries, especially Peru, are more sensitive to issues of sustainability and the absence of xenobiotic residues in food products. The Asian region, on the other hand, is primarily concerned with controlling the food supply and biosafety, particularly through technological developments (Alltech, 2020).

In light of these challenges, there is a case for looking ahead to how to ensure food security in future decades. The questions are not only about availability, but also about the other dimensions of food security and safety.

3. Elements of hope

There are several ways to meet the challenge of ensuring sufficient food availability in the future: consume less and produce more, or at least maintain the current capacity of food production systems. A human being needs about 2500 kcal of metabolizable energy per day, and about 1 gram of protein per kilo of body weight, or about 12% of energy intake. Half of these proteins should be of high biological value, rich in essential amino acids, and with a profile similar to that of human tissue. Proteins that meet these criteria are generally of animal origin. In a growing number of countries, humans can be considered to consume twice this amount, for hedonic reasons. These are also partly responsible for the obesity epidemic in the human population.

To a first approximation, the animal and its food products are the result of a process of concentration of the proteins - often of plant origin - that it ingests, associated with a refinement of their quality. Ruminants are an exception to this rule, as the flora of their pre-stomachs is able to synthesize microbial proteins of very high biological value from proteins of mediocre quality, for example from cereals, or even from non-protein nitrogen such as urea. However, the basic principle behind the construction of the individual remains similar: the animal extracts from food the essential amino acids that it cannot synthesize itself, and stores them in its body proteins or exports them in products such as milk or eggs. The efficiency of this storage process is unfortunately low. In the best of cases, it is around 50%, for example in genetically selected poultry. It is zero for non-productive animals whose feed consumption only allows them to maintain a stable weight. In addition to the quantitative conversion, it is also necessary to consider the qualitative issues. Indeed, the consumption of a cereal by an animal gives it a competitive character with respect to the human being. On the other hand, coarse plant products are not, in the current state of our knowledge, a source of nutrients for the human species, but they can be perfectly valued by a ruminant to ensure, at a minimum, its survival. In summary, for every calorie ingested by humans, the calorie from animal products requires twice as much agricultural land as its plant counterpart. The reduction in demand for agricultural land can therefore result from a reduction in the consumption of animal products in favor of other ingredients. It is then based on a modification of the consumer's plate.

On the other hand, a decrease in food demand may be the result of better control of food losses and waste. Losses are often related to the initial and intermediate stages of production, for example in the case of crop diseases or animal epidemics requiring slaughtering. Waste is more likely to be related to losses at the end of the production chain, such as unsold products that are destroyed or food that has passed its sell-by date. Losses are more frequent in countries with low technological development, while wastage is more frequent in countries with food glut situations. Waste can also occur at the beginning of the production chain in low-income countries. For example, slash-and-burn agriculture consists of cleaning and fertilizing soils with minerals by burning natural or crop straws. In addition to mortgaging the organic matter load of soils, this practice potentially deprives animals such as ruminants of a source of food, or farmers and herders of another form of resource utilization, if they had the technology to use it.

A second way to support food security would be to maintain and increase agricultural production and capacity. This approach seems conceivable only by increasing crop area or food production per unit area. This is a considerable challenge, and probably the second option is the most promising, both for environmental reasons related to the conservation of areas dedicated to biodiversity, and for reasons of physical constraints.

The potential for increasing agricultural productivity is high. There is a logarithmic relationship between the application of crop protection agents, mainly fertilizers and pesticides, and agricultural yields. The latter can be increased tenfold by moving from the worst cultivation conditions - lack of fertilizer, low water availability, low technological development, low farmer training - to the best. Belgium, for example, has grain productivity of nearly 10 tons of dry matter per hectare, compared to less than 2 tons for most less developed countries (Figure 4). The application of inputs, however, has adverse environmental consequences. Technologies to provide plants with essential nutrients in a "targeted, timely" manner to maximize the efficiency of their use, without losses through runoff or leaching, should be enhanced. In this regard, it should be noted that the African continent, with the possible exception of the Congo Basin, is largely covered with areas that are not very suitable for intensive agriculture but are well adapted to extensive livestock farming. In other words, the continent can easily produce beef, sheep or goat meat, but at a slow pace, due to the low energy value of natural pastures. This should be taken into account in agricultural development policies.

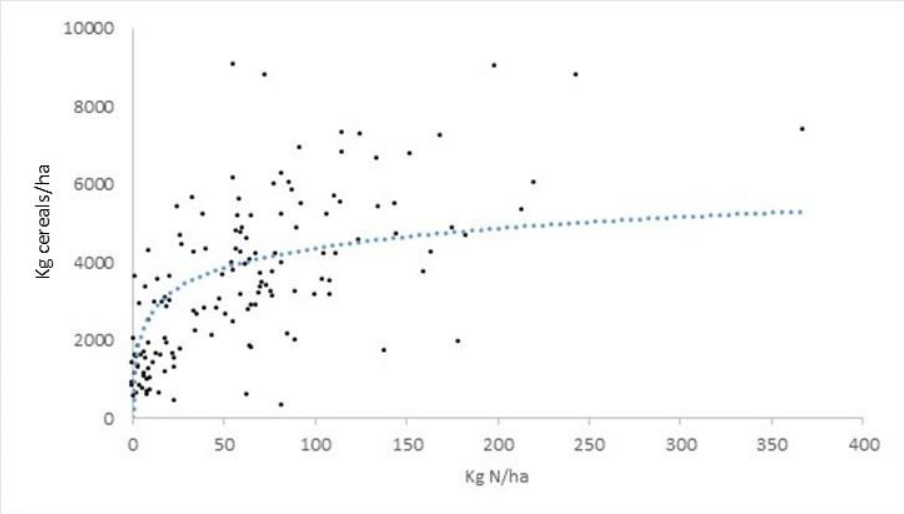

Figure 4. *National cereal production in the world as a function of nitrogen application per hectare (from FAO, 2020).*

Promoting technologies, their synergy and improvement can play a decisive role in achieving future global food security. Engineers have developed tillage techniques that are more respectful of soil structure. They reduce erosion and promote carbon storage in the soil. On the other hand, legumes can be valuable allies in enriching the soil with nitrogen without the need for nitrogen fertilizers, thanks to their root structures that host rhyzobial saprophytic organisms capable of transforming atmospheric nitrogen into plant-available nitrogen. Satellite technologies, on the other hand, provide valuable information to optimize land use in time and space. But one of the greatest advances will probably come from revolutions in the genetic sciences. It is now possible to rewrite short excerpts of an organism's genetic code to try to improve its performance, thanks to CRISPR-Cas9 technology. On the other hand, gene editing is now reaching unprecedented levels of speed and execution.

The first approach-genome rewriting-is likely to face many obstacles due to critics-rightly or wrongly-of the use of genetically modified organisms. Yet the technology is worth considering for the benefits it could bring (Rao, Wang, 2021). For example, the photosynthetic efficiency of plants - currently close to 1% - could be improved. But it would certainly raise the question of the risk of losing control over the propagation of plants that have become more competitive with their natural relatives. This simple example shows the caution with which these technologies must be used. Genomic editing, on the other hand, should make it possible to rapidly identify individuals - animals or plants - with a competitive advantage over their congeners. As founders of new lines, they would be endowed with resistance to biological or abiotic factors that are harmful to productivity. We can think of resistance to drought, high temperatures, or critical diseases. However, such individuals could also generate lines that farmers or breeders would not have more control over in case of genetic escape.

In this context, training, education and the transmission of knowledge will play an essential role. How can fertility of the land be preserved? How can the ecological conditions of breeding be improved in order to protect the animals from stress? How can food supply for animals be ensured with resources that are not competitive for humans? Some of the answers to these questions potentially exist in the endogenous knowledge of farmers, but they are not necessarily known and put into practice by farmers who are deprived of quality knowledge transmission. This endogenous knowledge risks being forgotten in the event of a generation gap following the migration of young people to the cities, and their progressive disinterest in agriculture and livestock breeding.

4. Conclusion

Food security and safety are strategic issues for peace. Their contribution to peace can only be guaranteed if the supply of food and the demand for it are kept in balance. Many means are currently available to us to reach this objective. Some of them are known and theoretically within reach. Seeking to optimize the consumption of animal products, for example, is concretely achievable on an individual basis, or even on a collective basis if food policies lead to it through awareness programs. The latter can also target the issue of waste. Controlling food losses is already more complex, as it requires a better control of animal or plant diseases, or better access to modern agricultural technologies without increasing the pressure, *in extenso,* on the ecological environment. Scientific innovations, on the other hand, have been regularly modifying the existence of human beings for more than a century and accompany demographic growth. Their major importance cannot be denied, considering the proportion of the population that benefits from them. Nevertheless, one cannot deny the impact that they have had and continue to have on the planet, due to the fossil fuel consumption that most of them require and the residues they generate. A trivial example is the production of urea for agricultural purposes. However, technologies under development or to be developed in the future suggest opportunities to improve global food security with highly targeted tools whose environmental impact could be negligible. It is not possible to make even a partially exhaustive inventory of these technologies in the context of this article. But they could include, for example, viral vaccines using voluntarily mutated variants in a controlled manner, preventing the reversion of the agent into its pathogenic form, or products derived from messenger RNA technologies, which offer the prospect of unprecedented applications. In principle, these technologies require little or no energy. They rely on the capacity of the individual - animal or plant - to mobilize its own resources. They will therefore play a key role in reducing losses in the food chain and even in improving productivity. However, the question arises as to the extent to which these technologies will be under control, accessible to the greatest number of people, and will not be the object of a competitive trade that will leave out the poorest people or countries, as is currently the case in the context of the prevention of human coronavirus-related diseases.

Another issue, more related to food safety, concerns the problem of plastic packaging, whose impact on the food chain is disastrous. They play an unfortunately important role as micro-containers and guarantors of a certain hygiene, which makes them tools of social justice and accessibility to healthier food, especially in cities. Here again, we can hope that researchers will quickly develop technologies either able to replace these compounds in an ecological way, or able to degrade them. These packages are a reflection of our dependence on so-called "fossil" resources and on organic chemistry, the chemistry of synthesis, which is the mainstay of technological developments. This science is also an instrument of justice by allowing the transport and preservation of foodstuffs between producers and consumers who are far apart. Certainly, some countries have the opportunity to develop a local, almost decarbonized agriculture, which could significantly contribute to cover the needs of their population in quality food. Others, on the other hand, would undoubtedly experience famine if they were to go down this path, due to imbalances between population density and land productivity.

The dark side of this chemistry is having a growing impact on the climate and the environment, and it is therefore a priority to free ourselves from it as quickly as possible by developing ecological alternatives that are at least equivalent in economic terms. And in this respect, it is difficult to see which sector other than research would be able to meet this challenge. Significant public funding would probably help to ensure a more equitable distribution of the added value generated by these future technologies.

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