The dimensions of Food Security and Safety: cross views and perspectives

Abstract.

This paper gives an insight into the evolution and structuration of Food Security and Safety from a historical and spatial perspective. Food Security and Safety is based on five internationally recognised pillars, i.e., availability, accessibility, adequate use, stability and production sustainability of food. They are largely inspired by ancient concepts that have transcended Mankind since the advent of culture. Today, Food Security and Safety is highly specialised from various points of view, e.g., spatial and professional. This specialisation is quite dependant on fossil energy resources, which poses a great danger to the stability and the guarantee of peace in the world, unless these resources are properly allocated.

Introduction.

Finding food is a central concern to all living things. However, Food Security and Safety (FSS) is associated with mankind alone, due to the human ability to project in the future. The importance of this concern precedes that of education or health all over the world (Farrukh et al., 2020).

The Food and Agricultural Organization provides a strict definition of Food Security and Safety (FSS) according to the World Food Summit of 1996. The concept could be summarised like this: food must be physically present anywhere, according to the dimension of “Availability”; it must not have deleterious effects, neither on the short term – for example due to the presence of toxic compounds-, nor on the long term, i.e., diet must be nutritionally balanced and complete. This is the dimension of adequate food “use” from a safety point of view. Everyone must be allowed to procure food according to the most economical way, understood from various points of views such as the financial or mental ones. This refers to a notion of market “accessibility” and can lead to behaviours falling within the scope of games theory, such as strategies for setting up food reserves. Food has to be present in a near and more distant future. This is the concept of food supply “stability”. And finally, there is a belief that future generations must be allowed to benefit from the same rights as we do: food availability strategies have to be implemented in a sustainable way, throughout the concept of “sustainability”.

It could be considered that FSS have been governed by similar mechanisms throughout human history, but they became structured over time and grown more complex as human society evolved. This point of view is developed in this article.

Historical point of view.

Food security and safety evolved in time and space, according to a Darwinian process or – if one dare use such a neologism – to a Prigoginian way[1]: very simple and poorly planned at the beginning, it gradually became more structured and complex as humanity expanded energy use.. At the beginning, the energy chain is initiated by the sun that provides the Earth with a level of energy close to 1000

[1] According to the Nobel Prize Prigogine, when a system receives energy, it moves away from equilibrium and becomes more complex (Prigogine, 1996).

Watts/m² (Figure 1). Only a small fraction of this energy, close to one thousandth[2], reaches the ground and is transformed, through photosynthesis, into organic plant matter. This matter enters a transformation chain including herbivore, prey and predators, going as far as hypercarnivores whose lifespan depends only on their natural longevity.

Mankind has reached the top of this ecological pyramid, thanks to its intelligence. About 10 thousand years ago, humanity created its own food pyramid, that appended to – or even parasitized, from a certain point of view – the natural ecological pyramid. To this day, about two thirds of Earth's ecosystems have been altered by humanity. In 2000, half of habitable lands (including forests) was already used for agriculture and breeding activities (Ellis et al., 2010). Food Security and Safety is thus a concept immanent to mankind.

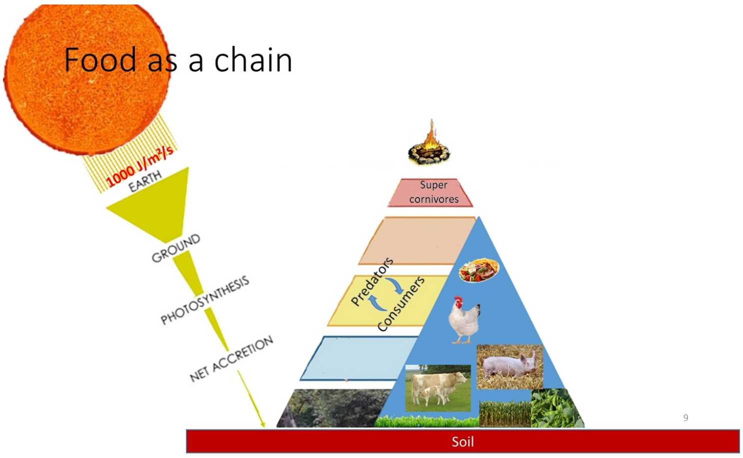

Figure 1. Energy transformation into ecological and food pyramids[3]

Mankind has always eaten spoiled foods, but certainly not by choice. The methods to evaluate spoiling levels relied on senses: vision, smell, or taste. To conceal spoilage, people have salted, dried, fermented, smoked, sometimes chilled food. Since the Antiquity, spoilage was a great concern and Hippocrates already recommended eating healthily, according to a grid of criteria such as temperature or moisture, certain combinations being suitable or unsuitable for humans to consume (Birlouez, 2019).

Later, during the Middle Ages, especially during the Little Ice Age (14th century and later), harvests were poor, and hard to preserve – in any case never over 2 years. Frequently, they were spoiled by yeast contaminants. People threatened to revolt and the authorities often failed to provide people with sufficient food supply of sufficient relative quality. For example, in Liege, Paris or Venice, artisans had to procure raw food material at markets, not only to allow authorities to collect taxes, but also to allow price controls, to be able to verify that the meat came from healthy enough farm animals, and to assess the freshness of fish or the quality of flour. Artisans were not allowed to raise more than one sow and one or two pigs, to avoid excessive cereal waste on animal feeding. By the end of the 15th century, the big Flemish cities tackled prices liberalisation in order to forbid the exportation of harvests towards the rich Mediterranean Basin (Litzenburger, 2016). The authorities' concern with food allocation control is thus nothing new.

[2] This value is easily computable considering that the most productive ecosystems generate about 10 to 30 tons total of organic matter per ha and per year, i.e., 1 to 3 kg per m² per year, and that organic matter – dominated by carbohydrates – contains about 17 KJ gross energy/kg.

[3] For details onto conversion efficiency of solar energy into biomass : see Zhu et al., 2008. See also footnote 2.

At the end of the 18th century, the industrial revolution went hand in hand with the development of preservative techniques such as pasteurisation, appertisation or freezing, and chemistry – latter for better and sometimes for worse. The beginning of the 20th century was thus a period of relative FSS, but after the First World War, Europe experienced a situation of severe food insecurity, close to that observable today in a continent such as Africa: some countries went through famine and food shortages (e.g. Russia), and many other serious vulnerabilities (Figure 2).

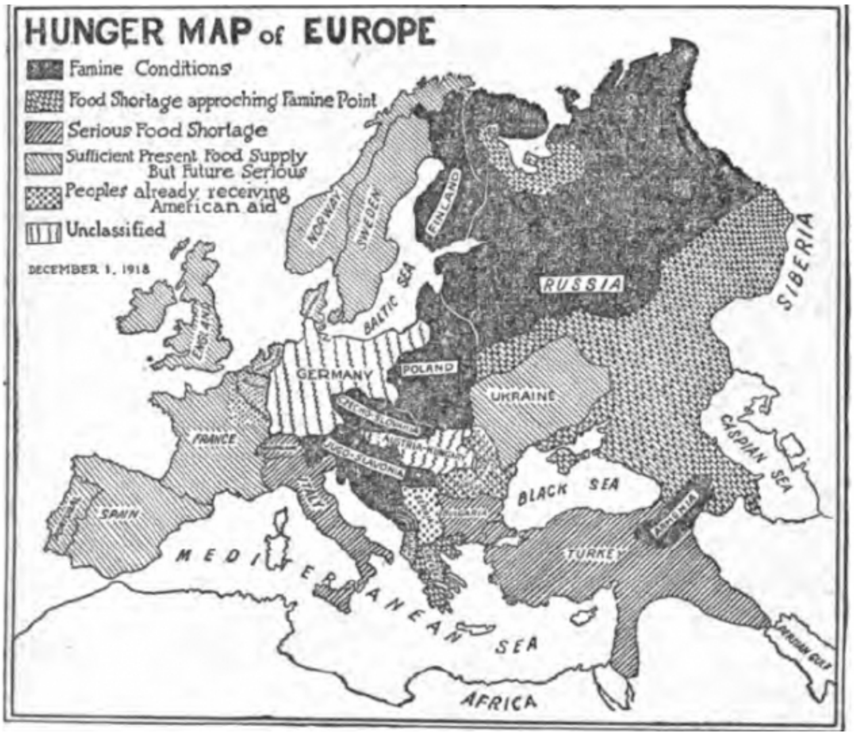

Figure 2. The hunger map of Europe immediately after the First World War. (From: The New York Times, 1919)

After the Second World War, due to the international dimension of the conflict, the United Nations' Directives were promulgated and Food Security became an inalienable right of individuals. During the following 30 years (called "The Glorious Thirties"), agronomy production increased sharply, quickly leading to a situation of high food availability, correlated with a linear increase of the world population. Today, this increase is still observable, especially due to the demographic growth in Africa (Figure 3).

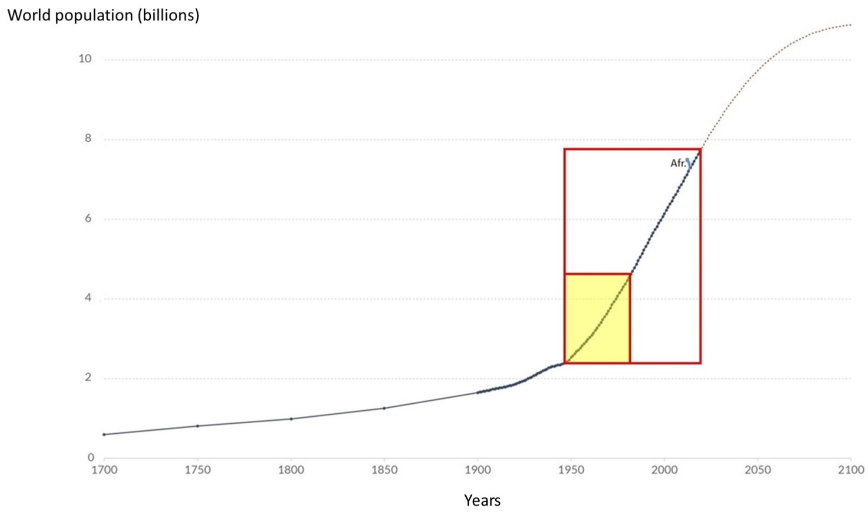

Figure 3. World population from 1700 to present, and future projections. The yellow rectangle points out “The Glorious Thirties” following the Second World War (From: ourworldindata.org)

By the 70’s, the oil shock actualized the perception of poverty and the associated problems of food accessibility. Consequently, cooperation policies engaged in strengthening capacity development of the poor. Shortly afterwards, at the beginning of the 90’s, sanitary shocks such as the mad cow disease or dioxin chicken scandals underlined the public value of healthy foods, and the importance of a balanced diet, as referred to the pillar of adequate food Use. Organic practices in agriculture thus began to emerge. Since the beginning of the 21st century, food has been produced more and more on the spot, and the international organisations strengthen the importance of food offer Stability (4th pillar) at an international level, in particular through a spatial dilatation of the food production. In parallel, mankind has become increasingly concerned about the very long-term availability of food to the benefit of the future generations, in reference to the 5th pillar of FSS, what tend to counteract this spatial dilatation.

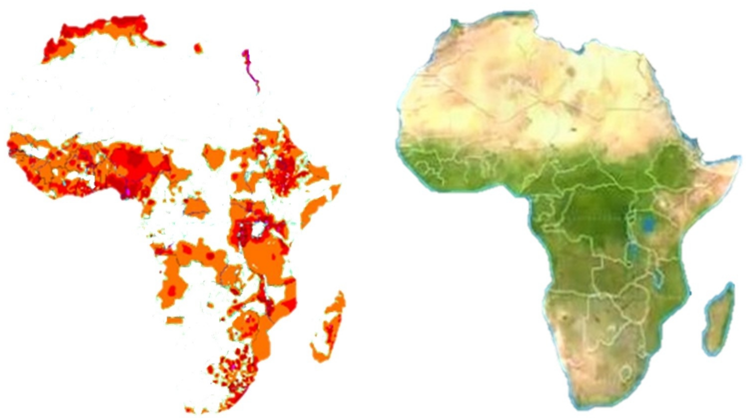

Figure 4. People density occupation (left) and vegetation cover (right) in Africa. (From: https://neo.sci.gsfc.nasa.gov/).

<u>Today</u>.

How is FSS structured today? It can be seen as a chain, with very high specialisation of agricultural production systems, the size of which is currently increasing (Wang et al., 2018). In a simple way, , it could be considered that the intensity of the photosynthetic activity on earth is well correlated with populations' density – except in dense forests. This phenomenon is visible on Africa, for example (Figure 4). This means that mankind is settled in areas where people can practice agriculture. The main farming activity clearly consists in cereal production – about 33% of all crops (FAO, 2020). Indeed, cereals – mainly wheat, maize, rice, barley - are the basis of the human diet. This production is clearly associated with the use of fertilizers, mainly nitrogen. Data from FAO demonstrates, if needed, a positive relationship between the use of nitrogen fertilizer and cereal production. This relation is far from linear, but rather Log-type or negative-exponential, with an annual production-plateau at about 5 t dry matter (DM)/ha, and an overall mean value across countries close to 4 t DM/ha. The cereal production never exceeds 10 t DM/ha (Figure 5). The data shows that half of the countries use no or very low amounts of nitrogen fertilizers, and consequently their agronomic productivity is very low, close to 1 or 2 t DM/ha. Moreover, 80% of the countries use less than 75 kg nitrogen fertilizer/ha, i.e., a single fertilizer bag for an area of 1-2 soccer fields.

Remarkably, for a given class of fertilizers, a large residual variation remains. Among the drivers that could explain why higher levels of cereal production are observed, there are, e.g. water availability, soil quality, implementation of technologies (tractors, precision agriculture,…), biotechnologies (GMOs, pesticides application,…), but also the education level, because higher educated farmers are more open to innovative approaches and more susceptible to develop endogenous innovations, as well (Farrukh et al., 2020). Belgium can thus easily be identified as a high-producing country, using high levels of fertilizers and reaching one of the highest cereal yield levels in the world. However, a country such as the Bahamas shows even higher production levels, despite using low levels of fertilizer. This observation would be worth investigating.

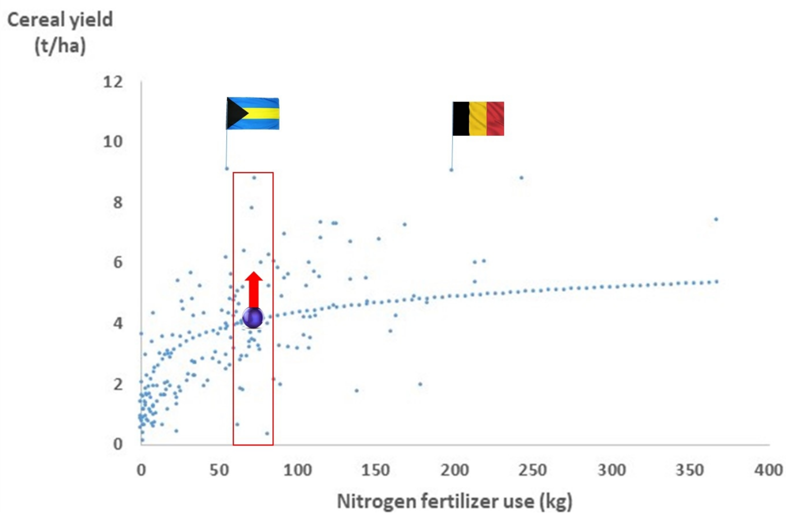

Figure 5. Relationship between national fertilizer applications and cereal productivity. The flags refers to Belgium and the Bahamas. (From: FAO (2020) data, reported by ourworldindata.org)

Interestingly enough, when considering a third dimension, the national annual cereal production per inhabitant, and assuming that the threshold for food security would be 1 kg cereal/d[4], i.e., 365 kg/yr, we can see that about 80% of the countries fail to guarantee this basic food security to their population. Some countries' current values far exceed the threshold and the most productive ones could probably be considered cereal exporters, such as the USA or Brazil.

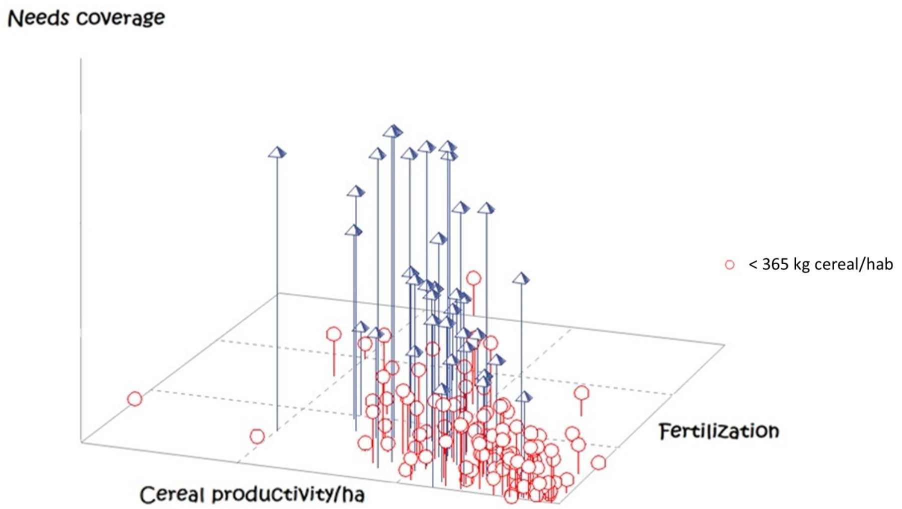

Figure 6. National population's coverage of cereal needs (kg cereal/habitant/year), according to nitrogen fertilization and cereal productivity per ha. The red circles report countries where cereal production is lower a threshold of 1kg/habitant/day). (From: FAO (2020) data, reported by ourworldindata.org)

If the primary productions, such as that of cereals or legumes such as soya, are important drivers of FSS, about half are milled into feed concentrate for livestock (by opposition to food, aimed at human) production, very especially corn and soya (Wang et al., 2018). The world feed production is impressive and now reaches about one billion tons/yr – a 1 km-side cube , with an annual increase close to 4% (Figure 7). Such an amount requires sowing a surface close to that of Europe Union each year[5].

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[4] Assumption based on the fact that 1kg cereal contains about 13000 kJ metabolisable energy, what support with security margin requirements for maintenance and active life in man and women according to Calerie study group, 2014.

[5] Calculated like this : we considered that (1) maize and soybean meal are the two main drivers of a structured animal production (Wang et al., 2018), (2) the highest soybean meal productivity is close to 2.5 tons/ha (Gaitan-Cremaschi et al., 2015), (3) while that of maize is 7.7 tons/ha (Nabout et al., 2012). Adjusted at a realistic worlwide average value of 3 tons/ha for the both ingredients, one billion tons feed require sowing a surface of 3,3 millions km², close to EU surface.

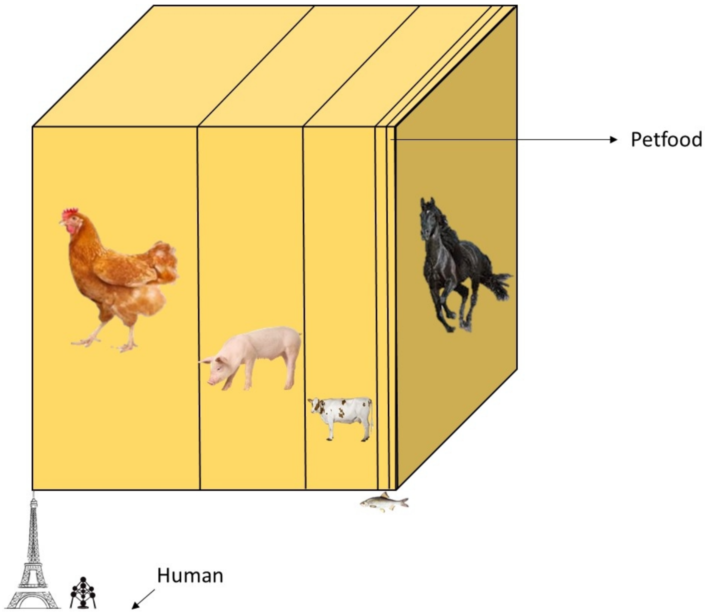

Figure 7. Illustration of the volume as a one-km-side cube, and of animal species allocation of feed produced annually worldwide. (From: Altech® data, https://www.Altech.com. Global feed survey, 2020).

Trade market evolution is such that feed is actually provided and used worldwide for all domestic species, even in the most remote places. About 40% of the feed production is dedicated to poultry farming, 30% in pig production, 15% in cattle production (milk and meat) and 10% in fisheries. The remainder is used in pet food – mainly -and horse feeding. It is important to point out that the total amount of animal production allowed by this feed is quite sufficient to provide animal protein – and even protein strictly speaking - to the whole of humanity.

The main concern is related to the accessibility of people to primary (plant production) and secondary (animal production) food. Indeed, we can estimate that about 25% of humanity suffers from undernutrition, while another quarter is overfed. An exemplary illustration of imbalance in food trade is the world meat export-import flows. The two giants of meat export are Brazil and New Zealand, while the giant of meat import is China, which could be called a "vortex of meat absorption" (Figure 8). At national levels, clear poverty contrasts are also observed between rural and urban areas. For example, due to the first Covid-19 outbreak, it was estimated that, in April 2020, the poverty level increased by 15% in rural areas but up to 25% in cities, the situation being even worse in Sub-Saharan Africa (http://idele.fr/; Sumner, 2020 ; Swinnen, 2020). This is of special concern in the countries that not only have a food productivity lower than what their population requires, but also shows low GDP per inhabitant. These countries are both net food importers and not creditworthy.

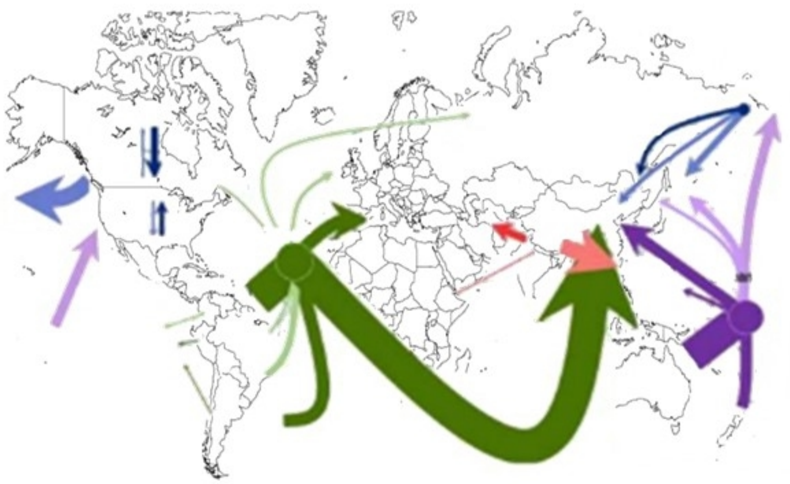

Figure 8. Main international meat flows worldwide. (From: http://idele.fr).

For now, new paradigms and practices are being explored in order to keep FSS stable. At that level, the Covid-19 outbreak could be a trigger point for significant changes (Bakalis et al., 2020). The new keywords are based on trusty production practices for healthy and sustainable food production systems. They are alone an extension of the evolution of FSS that has just been described above. The associated practices are very large and include smart technologies, alternative protein production systems, social changes in food habits, wastes reduction (Aikin and de Boer, 2018; Meybeck et al., 2018). However, for now there seems to have weak evidence indicating that the new practices could meet the challenge of FSS in the future, especially at the level of food global availability. Climate change is the crossroads of these concerns.

Tomorrow.

Climate change could worsen the situation of the poor in the future. Positive temperature abnormalities in particular (excepted in the North of the USA and in Canada, according to https://neo.sci.gsfc.nasa.gov/) observed around the World in 2020 could be indicators of future difficulties in water use, in legitimacy of fossil energy resource uses, and consequently on applied and fundamental research in sectors of technology and biotechnology, and on education, which both largely depend on these fossil resources. Besides the increase of global temperature itself could jeopardise population growth attributable to non-optimal temperature (Bukart et al., 2020), an inadequate evolution might lead to major conflicts in the world, as a response to competition for resource allocations.

Mankind is probably at a crossroad and it has become urgent to elaborate clear strategies in order to absorb the shocks we will face in a near future. Probably a first important response would be to make great efforts in order to save water and fuel energy, giving space for investing in fundamental and applied research aimed at quickly improving the use of solar energy, and investing in education. This would give some guarantees for peace.

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