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The Dimensions of Food Security and Safety: Cross Views and Perspectives*

by

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Summary. — 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 recognized 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 specialized from various points of view, *e.g.*, spatial and professional. This specialization is quite dependent on fossil energy resources, which presents a great danger to the stability and guarantee of peace in the world, unless these resources are properly allocated.

Introduction

Finding food is a central concern to all living beings. However, food security and safety (FSS) is associated with mankind alone, due to the human ability to project into 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 (FAO) provides a strict definition of FSS according to the World Food Summit of 1996. The concept could be summarized as follows: 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 get food according to the most economic way, understood from various points of view 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 should 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 has been governed by similar mechanisms throughout human history, but these have become more structured over time and more complex as human society has evolved. This perspective is developed in the present paper.

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Historical Point of View

Food security and safety has 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. Originally, the energy chain is initiated by the sun that provides the earth with a level of energy close to 1,000 watts/m² (fig. 1). Only a small fraction of this energy, close to a 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 ten thousand years ago, humanity created its own food pyramid, which 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). FSS is thus a concept immanent to mankind.

Mankind has always eaten spoiled food, 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 has been 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).

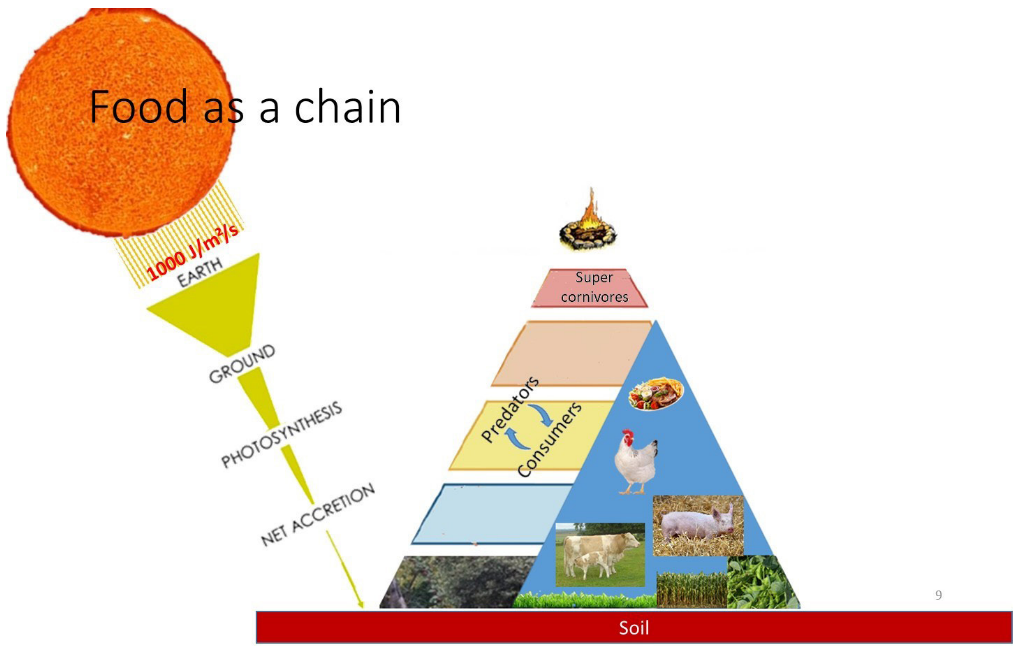

Fig. 1. — Energy transformation into ecological and food pyramids [3].

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 more than two years. Frequently, they were spoiled by yeast contaminants. People threatened to revolt and the authorities often failed to provide them with sufficient food supply of sufficient relative quality. For example, in Liege, Paris

* Numbers in brackets [ ] refer to the notes, p. 186.

or Venice, artisans had to get raw food material at markets, not only to allow authorities to collect taxes, but also to allow price controls, to be able to check 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 had tackled price liberalization 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.

At the end of the 18th century, the industrial revolution went hand in hand with the development of preservative techniques such as pasteurization, appertization or freezing, and chemistry — the latter for the better and sometimes for the worse. The early 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 (fig. 2).

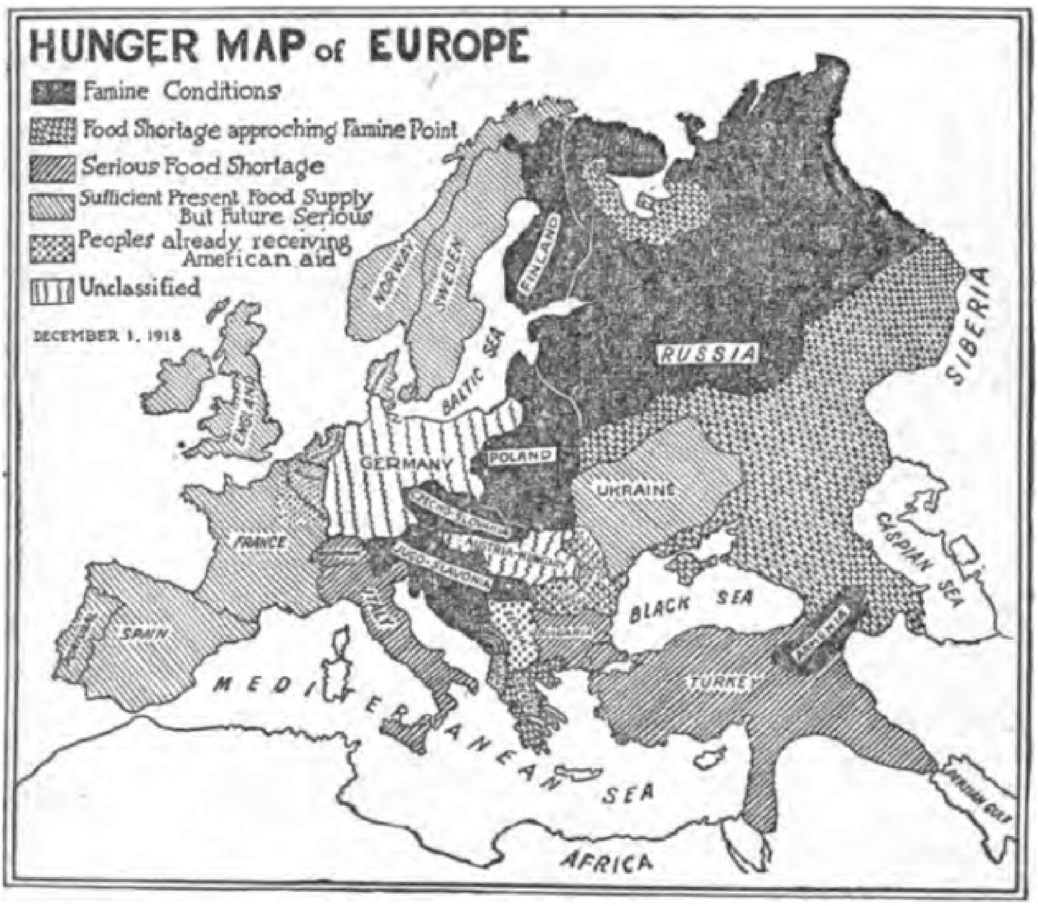

Fig. 2. — The hunger map of Europe immediately after the First World War (from *The New York Times*, 1919).

After the Second World War, due to the international dimension of the conflict, the United Nations' Declaration of Human Rights was promulgated and food security became an inalienable right of all individuals. Over the next thirty years (called "The Glorious Thirty"), 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 (fig. 3).

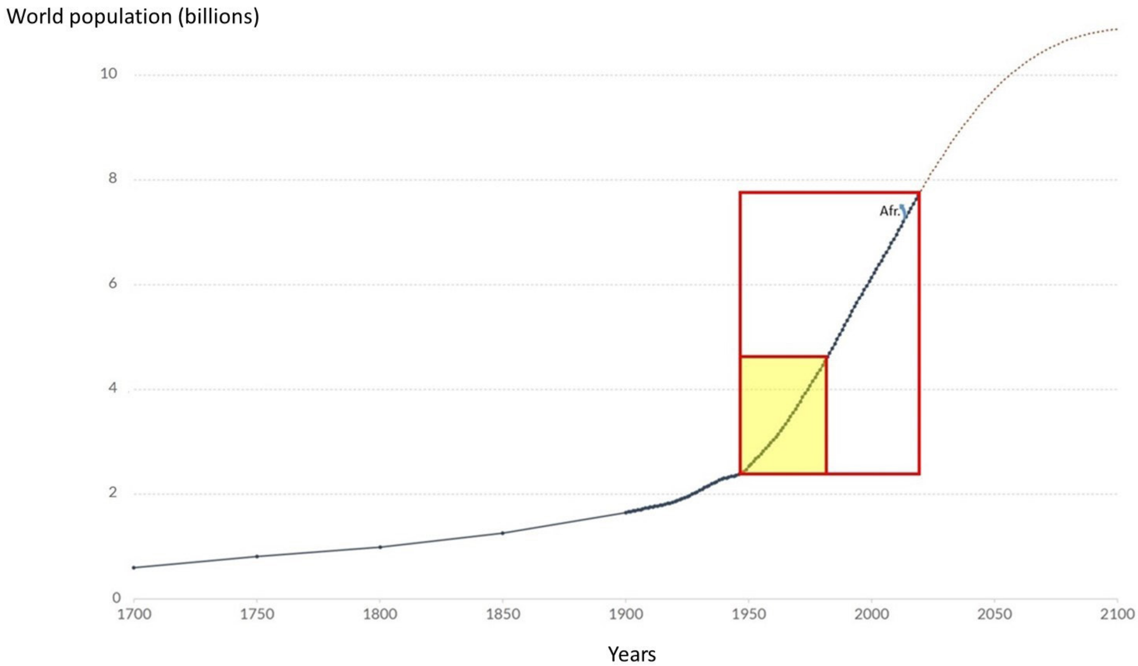

Fig. 3. — World population from 1700 to present, and future projections. The yellow rectangle points out “The Glorious Thirty” following the Second World War (from https://ourworldindata.org/).

By the 1970s, the oil shock actualized the perception of poverty and the associated problems of food accessibility. Consequently, cooperation policies committed to strengthening capacity development of the poor. Shortly afterwards, in the early 1990s, health crises such as the mad cow disease or dioxin chicken scandals emphasized the public value of healthy food and the importance of a balanced diet, as referred to the pillars 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 organizations have strengthened the importance of food offer stability (fourth pillar) at an international level, in particular through a spatial dilatation of food production. In parallel, mankind has become increasingly concerned about the very long-term availability of food to the benefit of future generations, in reference to the fifth pillar of FSS, what tends to counteract this spatial dilatation.

Today

How is FSS structured today? It can be seen as a chain, with very high specialization 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 population density, except in dense forests. This phenomenon is visible in Africa, for example (fig. 4). This means that mankind is settled in areas where people can practise agriculture. The main farming activity clearly consists in cereal production — about 33 % of all crops (FAO, 2020). In fact, cereals — mainly wheat, maize, rice, barley — are the basis of human diet. This production is clearly associated with the use of fertilizers, mainly nitrogen. Data from FAO demonstrate, if needed, a positive relationship between the use of nitrogen fertilizers and cereal production. This relation is far from linear, but rather Log-type or negative-exponential, with an annual production plateau of about 5 t dry matter (DM)/ha, and an overall mean value across countries close to 4 t DM/ha. Cereal production never exceeds 10 t DM/ha (fig. 5). Data show 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 fertilizers/ha, *i.e.*, a single fertilizer bag for an area of one to two soccer fields.

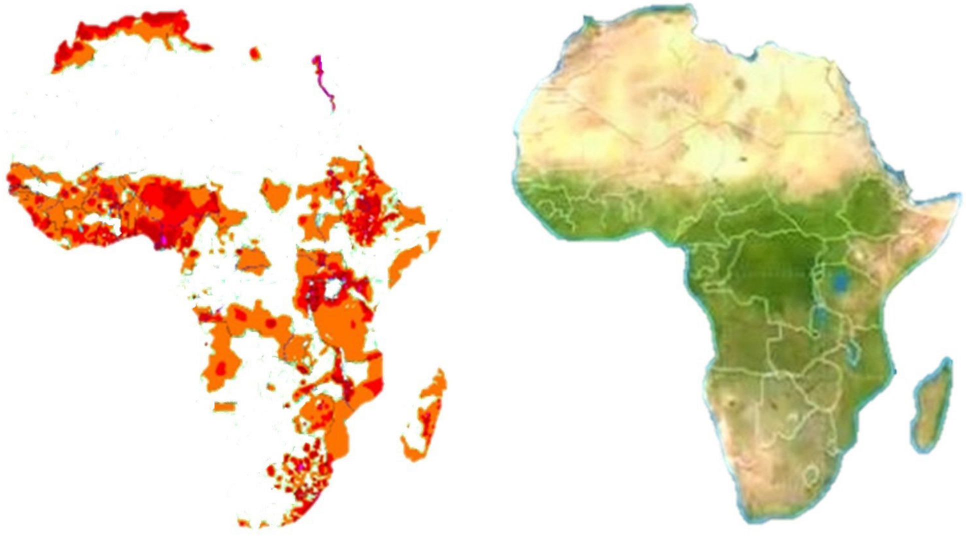

Fig. 4. — People density occupation (left) and vegetation cover (right) in Africa (from https://neo.sci.gsfc.nasa.gov/).

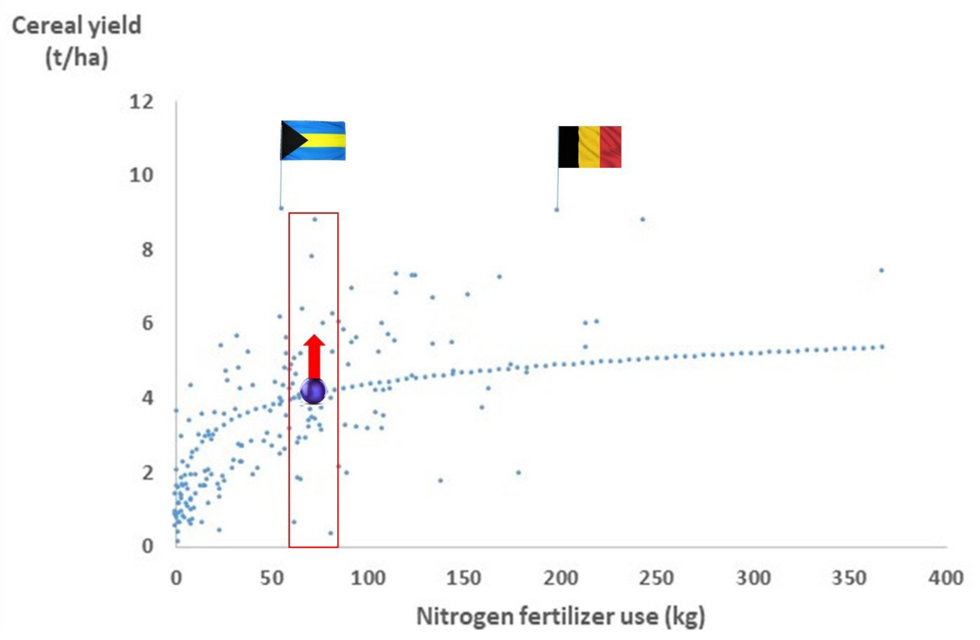

Fig. 5. — Relationship between national fertilizer applications and cereal productivity. The flags refer to Belgium and the Bahamas (from FAO (2020) data, reported by ourworldindata.org).

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 water availability, soil quality, implementation of technologies (tractors, precision farming,…), biotechnologies (GMOs, pesticide application,…), but also education level, because higher-educated farmers are more open to innovative approaches and more likely 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.

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 (fig. 6). 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.

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

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

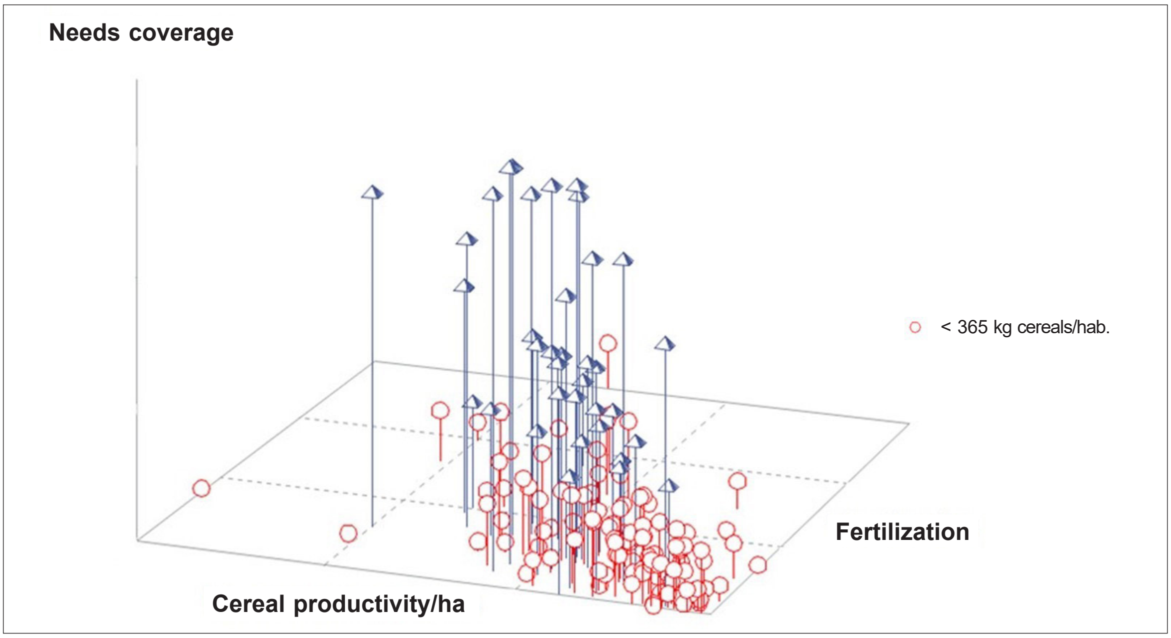

Fig. 6. — National population coverage of cereal needs (kg cereal/habitant/year), according to nitrogen fertilization and cereal productivity per ha. The red circles report countries where cereal production is lower than a threshold of 1 kg/habitant/day (from FAO (2020) data, reported by https://ourworldindata.org/).

The main concern is related to the accessibility of people to primary (plant production) and secondary (animal production) food. In fact, we can estimate that about 25 % of humanity is suffering from under-nutrition, 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" (fig. 8). At national level, 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 *et al.*, 2020; Swinnen & McDermott, 2020). This is of special concern in countries that not only have a food productivity lower than what their population requires, but also show low GDP per inhabitant. These countries are both net food importers and not creditworthy.

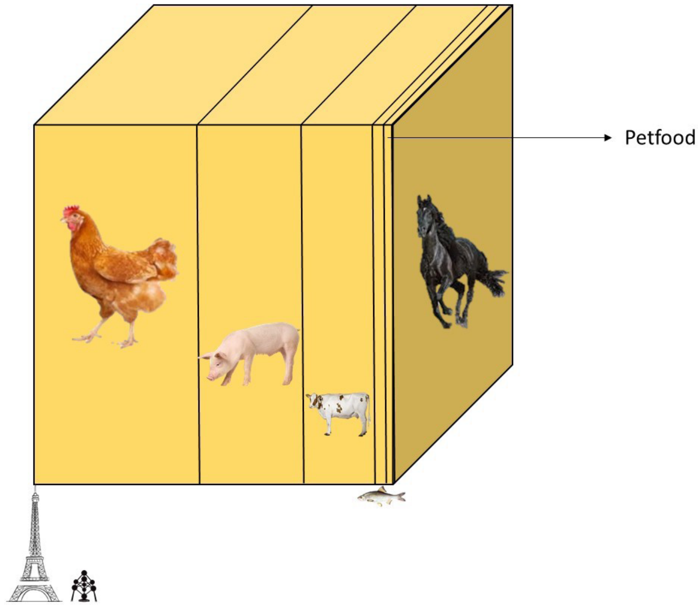

Fig. 7. — Illustration of the volume as a 1-km-side cube, and of animal species allocation of feed produced annually worldwide (from Altech® 2020 Global Feed Survey, https://www.Altech.com).

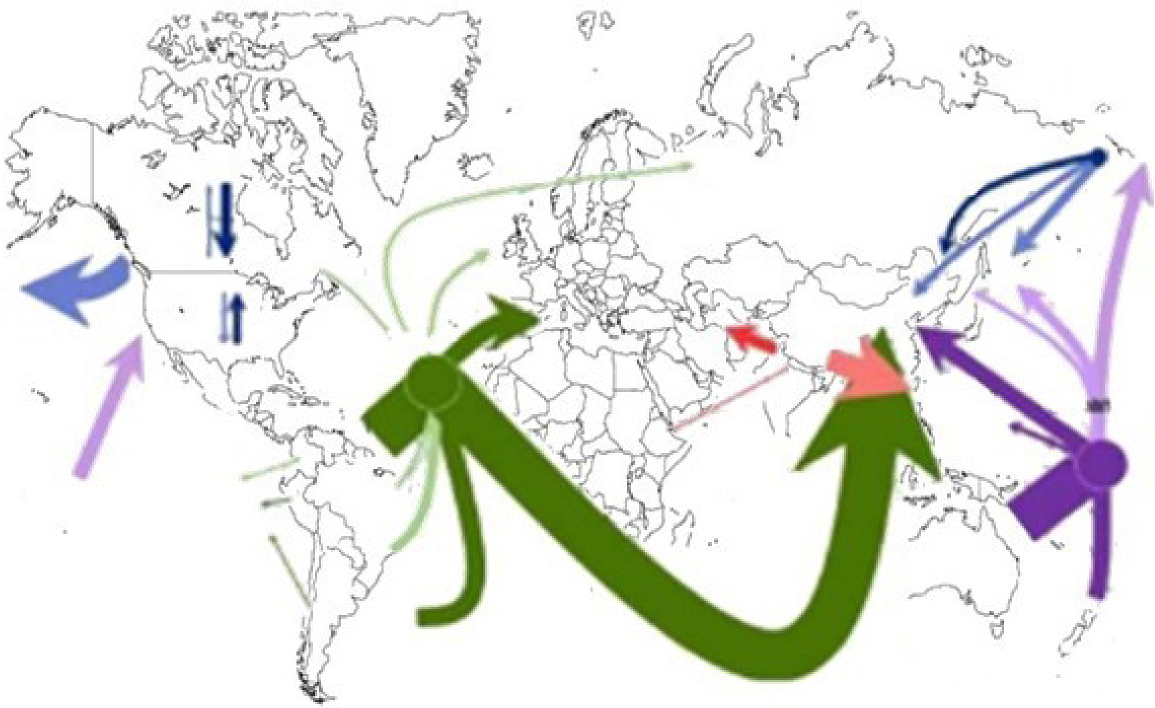

Fig. 8. — Main international meat flows worldwide (from http://idele.fr).

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, which has just been described above. The associated practices are very large and include smart technologies, alternative protein production systems, social changes in food habits, waste reduction (Aikin & de Boer, 2020; 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 at the crossroads of these concerns.

Tomorrow

Climate change could worsen the situation of the poor in the future. Positive temperature abnormalities in particular (except 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 use, 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 fact that the increase of global temperature itself could jeopardize population growth attributable to non-optimal temperature (Burkart *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 crossroads and it has become urgent to develop 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.

NOTES

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

[2] This value is easily computable considering that the most productive ecosystems generate about ten to thirty tons 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 on conversion efficiency of solar energy into biomass, see Zhu *et al.*, 2008. See also note 2.

[4] Assumption based on the fact that 1 kg cereals contains about 13,000 kJ metabolisable energy, which supports with security margin requirements for maintenance and active life in man and women according to Redman *et al.*, 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 t/ha (Gaitán-Cremaschi *et al.*, 2015), (3) while that of maize is 7.7 t/ha (Nabout *et al.*, 2012). Adjusted at a realistic worlwide average value of 3 t/ha for both ingredients, one billion tons feed require sowing a surface of 3.3 million km², close to EU surface.

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