PART 1

Food and Sustainable Development Challenges

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Food: Issues and Challenges

1.1. History and roles of food

Providing food is one of the major human activities, both for individuals and the organization of societies. Eating meets a vital need, but is also a source of questioning on the impacts of this diet on health. The solutions sought to meet this need vary according to different ethical, religious, community, social and other criteria. These solutions rely on anthropological, legal, health, chemical or microbiological studies and analyses. Indeed, the term "food" is a polysemic: it refers just as much to a science, a context and an industry. The social and scientific questions related to this term have not ceased to evolve over time, with the consequence that more and more scientific disciplines have become involved in this field.

These questions have always connected food to agriculture, livestock and fisheries. Even before the existence of organized agriculture, hunter-gatherers had to deal with concerns about their food, including preserving a level of hygiene, making it edible, as well as preserving food for "delayed consumption" when cultivation was not possible. These challenges remain and are the essential foundations for a history of food. To illustrate the main stages of this food history, Table 1.1 presents some key dates. These dates illustrate the various means implemented to ensure, first, a delayed consumption of food and then, gradually, the complementary search for flavors, tastes, textures and savors (olfactory sensations) that provide a new organoleptic[1] dimension that differentiates foods. These goals prompted the diversification of food sources and changes in diet. The history of various foods illustrates the evolution of consumer tastes and expectations. To illustrate, for a long time in France, white bread was a symbol of bourgeois wealth;

1 An organoleptic property is any aspect that can excite a sensory receptor.

in contrast to brown bread, which was consumed by subordinate social groups. It was not until the 1970s that the nutritional qualities of wholemeal bread (made with wholemeal flour) was discovered (Curtet 1998). The examples in Table 1.1 show that, in order to achieve food's key nutritional functions (providing essential nutrients for the body's make-up, maintenance and protection), it was necessary to develop physical, chemical and biological processes, either alone or in combination. It is thanks to these innovations that it has been possible to ensure the processing of agricultural raw materials and allow the development of a considerable range of attributes (criteria determining a food value).

Since the 1950s, there has been an acceleration in these dynamics of changes in food supply and expectations about food. Two major developments have been the development of transport and of the cold chain that significantly changed the link between agricultural production, location, processing, distribution and food consumption. In the aftermath of World War II, the ambition to feed the population led to the development of the contemporary dominant agro-industrial food system. Initially built to produce, process and distribute safe food, the system's objectives have evolved. Due to fierce competition, its development has produced new foods that create new perceptions and sensations for their consumers. In order to ensure the stability of industrial processes and the characteristics of the final products, a standardization of agricultural materials was carried out, which contributed to the reduction of biodiversity. Thereafter, the pursuit of innovation has focused on diversifying and strengthening the nutritional functions of differentiated foods that meet the needs of an increasingly diverse population. Finally, more recently, the agro-industrial system has integrated concerns about sustainability, including natural resources preservation, environment protection and various social issues – as the impact of the food on the health – into the design of food.

However, the impacts of food cannot be considered solely through the prism of a particular food product. The nature of the diet and the associated mental behavioral components are also essential considerations. Moreover, there are not one but many food models; however, this book focuses on the agro-industrial model developed in the industrial countries. Indeed, the development of industrial solutions, guaranteeing in particular low food costs (the share of the French household budget devoted to food was 25% in 1970 and 13% today) is predominant and has been accompanied by urbanization – a phenomenon that can be observed globally as consumers have relocated to cities, often far from agricultural production.

- 400,000	First proof of cooked food	
- 9,000	Cheese-making technology	Delayed consumption of dairy products
- 5,000	Drying of meat products in their own fat (Egypt)	First known application of meat product frying without vegetable fat
- 4,000	Beer fermentation	
- 3,000	Butter	
- 2,400	Beekeeping (Egypt) hive engineering	
- 2,000	Drying, salting, smoking of meat products (Babylon/Egypt)	Stabilization of meat products for preservation under non-controlled conditions
- 2,000	Noodles (China)	
- 300	Jam (Italy)	Packing and preservation
- 340	Sausages (Greece)	
- 350	Crystallization of sugar (India)	
1238	Different laws and regulations for brewing processes	First appearance of food regulation
1680	Fried potatoes (Belgium)	Use of vegetable oil
17th Century	Concentration of sugar cane juice: first fermentation and distillation of molasses	Example of circular economy and energy recovery and material saving
1735	Stock cubes (France)	Use of by-products to reduce loss and reduce waste
1756	Mayonnaise	
1780	Establishment of industrial plants for drying	
1797	Manual extrusion, used in 1920 for pasta	
1801	Beet sugar	
1804	First canned food	Preservation for delayed consumption

1842	Deep freezing of food	
1850	Thermal stabilization of wine: Louis Pasteur	
1866	Baby food (Nestlé)	Dried food products, long-term preservation without cooling
1869	Margarine, butter substitute: H. MegeMouries	Alternative to butter (animal product) with vegetable butter
1872	Spray drying of foods and powders	
1885	Popcorn machines (Charles Cretors)	
1893	UHT for liquids	
1886	Coca-Cola (John Pemberton, Atlanta, United States)	
1889	Dried coffee (New Zealand)	
1902	Hydrogenation of oils	
1902	Corn flakes (John Harvey Kellogg)	
1913	Aseptic processing of food	Food safety, preservation
1930's	Food storage in a controlled atmosphere	Packing and preservation
1940	Cleaning in dairy processes	Safe, sanitary dairy processes in particular
1945	Food irradiation	
1946	Microwaves	
2013	Artificial steaks, *in vitro*	

Table 1.1. *Examples of food history and associated discoveries*

1.2. Environmental impacts related to food

Food production represents at least a third of the production of greenhouse gases (but also 23% of the carbon impact, 23% of the water impact and 9% of the energy impact) (Martin 2015). Behind these data, there is a significant difference between the impacts of animal and plant resources: in the West, the ratio of the amount of plant protein ingested to produce one kilogram of animal protein is, on average, 7 for cattle, 6 for chickens and pigs, and 3 for eggs.

If we turn to the food processing phases, they impact the natural environment through wastewater discharges, particularly water withdrawals and significant energy consumption. Some aspects of the food production process, such as heat treatment, consume significant amounts of energy. Food packaging also has a major environmental impact through the waste it produces. Finally, in France, 25–30% of processed food is wasted (not consumed) and some studies estimate that controlling this waste alone would make it possible to address global food insecurity (Esnouf *et al.* 2011).

Minimizing waste during food processing and stabilization is an old issue. For example, sugar cane factories (see Table 1.1) historically have been self-sufficient in terms of energy and can even generate and supply electricity to the grid because a lot of work has been done to control their energy consumption. Moreover, beet sugar factories have gradually but dramatically reduced their water consumption and encouraged the reuse of process water. Some deli meats are also energy self-sufficient thanks to the reuse of animal fats. Today, energy accounts for only 3–15% of food processing costs and there is much engineering work underway to further reduce energy use. The optimization of transportation and warehousing is a vital area for further preservation, as the environmental impacts created by transportation can be significant. Finally, food storage (including refrigeration) and cooking also have significant environmental impacts.

However, the relationship between diet and environmental impact is complex. Foods with high energy density are the strongest contributors to the greenhouse effect; therefore, the higher the proportion of calories or dense foods consumed, the greater the impact per unit mass. But they are also the most satisfying and can therefore require smaller quantities. Contrary to beliefs, a good diet in nutritional terms has a powerful impact on the environment. Indeed, since a good diet includes low energy density foods, the amount consumed can be higher than in a high calorie diet (Darmon 2015). Eating habits are therefore crucial to the environmental impacts of our food. Reducing this impact means regulating consumption in terms of food choices and quantities consumed.

1.3. Food systems

The term "food" refers both to an individual process and to the services provided by one or more food systems that deliver food to populations. The term "food system" refers to "all the activities that contribute to the food function in a given society [...] the way in which people organize themselves to produce and consume, as well as the level and structure of their consumption" (Malassis 1994, p. 11). In other words, a food system refers to a production and consumption model it induces in a given space and context. It mobilizes its own actors, resources and means that enable it to produce and distribute food products/services. A food system constitutes of a specific implementation of the food function and the multiplicity of existing food systems synthetizes the various food offers in markets.

Today, in Europe, faced with the constraints and opportunities of sustainable development, food systems are being pressured to make unprecedented changes that relate to their four key stakeholders: public authorities, farmers, the agri-food industries, and consumers. Public authorities are introducing policies, regulations, action plans, scenarios, etc., to promote sustainability in all food systems and to ensure that citizens have sufficient food available in sufficient quantities, with sufficient hygienic and nutritional qualities to meet the required standards. At the same time, agriculture in developed countries is facing a difficult economic context as climate change poses a threat to plant and animal production in the required quantity and quality. To avoid the world without "agriculture" predicted by Peter Timmer in 2009 (Timmer 2009a), profound changes are required. That is the challenge of sustainable agricultural development faced with a concentrated, specialized and customer-oriented agro-industry and large-scale distribution (Timmer 2009b). The agri-food industries – interfaces between agricultural supply and demand requirements – are being questioned by a growing proportion of the population demanding unstandardized and sustainable food products. This societal demand calls not only for innovative products/services but also for "natural" foods, made with simple, healthy ingredients, produced with ethical practices while respecting the environment. A multitude of expectations must be met to satisfy these demands. It is necessary to develop products that make positive short- and long-term contribution to consumer health and are economically accessible, practical, tasty, nutritionally adapted and environmentally friendly. Finally, these products have to integrate values and symbols that are consistent with the beliefs of responsible consumers.

The development of such customized food products requires a systemic and multidisciplinary approach. It introduces a value chain approach to ensure a sustainable development path. In order to better illustrate the facts that have led the different food system stakeholders to seek new practices, in the following section we briefly review the strong ties that link the creation of food systems (FS) to the development of our modern societies (see section 1.3.1). Since there are not one but several FSs, we review the scientific literature to illustrate the factors that specifically characterize them (see section 1.3.2). We then outline in the chronological order of their appearance the major models of FSs in developed countries (see section 1.3.3). This definition of the major patterns enables us to establish the evolution of food consumption allowed by the successive and synchronous existence of these different FSs (see section 1.4). Section 1.5 provides an overview of the contribution of these production and consumption models to sustainable development issues. Finally, section 1.6 presents the challenges and issues facing food system actors (producers, processors, public policies and consumers) in order to increase the sustainability of the practices and products that characterize them.

1.3.1. *The emergence of food systems*

The food systems underpin our societal structures. Food systems have always been a major concern for humanity, because the existence and well-being of societies depend on the efficiency and quality of food production and distribution. The structures and dynamics of food systems are influenced by a set of elements (means, institutions, practices and actors), formal and informal relationships between their actors and the regulatory modes that govern them (e.g. market, conventions, norms and regulations). It is through these structures and their combinations that companies organize their food supplies and consumption (Esnouf *et al.* 2011).

The analysis of food supply from the food system(s) perspective first of all raises questions about how each of the food systems contributes to the satisfaction and evolution of the food provision. Second, the food system paradigm allows us to question the type of actors and activities that structure and animate the system. These include agriculture, transportation, processing, distribution and consumption. In order to integrate sustainable development into the food system through innovation, it is essential to consider the nature and impacts of the various activities and their interactions. Such a framework makes visible the relationships between the activities, flows, institutions and the knowledge necessary to feed a population.

Addressing food issues (eating or feeding a population) requires us to study the conceptual foundations of food systems, for which researchers have used two complementary methodologies. The first is the systemic approach and the second the historical and socio-economic approach. Figure 1.1 provides an overview of the two conceptual methodologies for studying food systems.

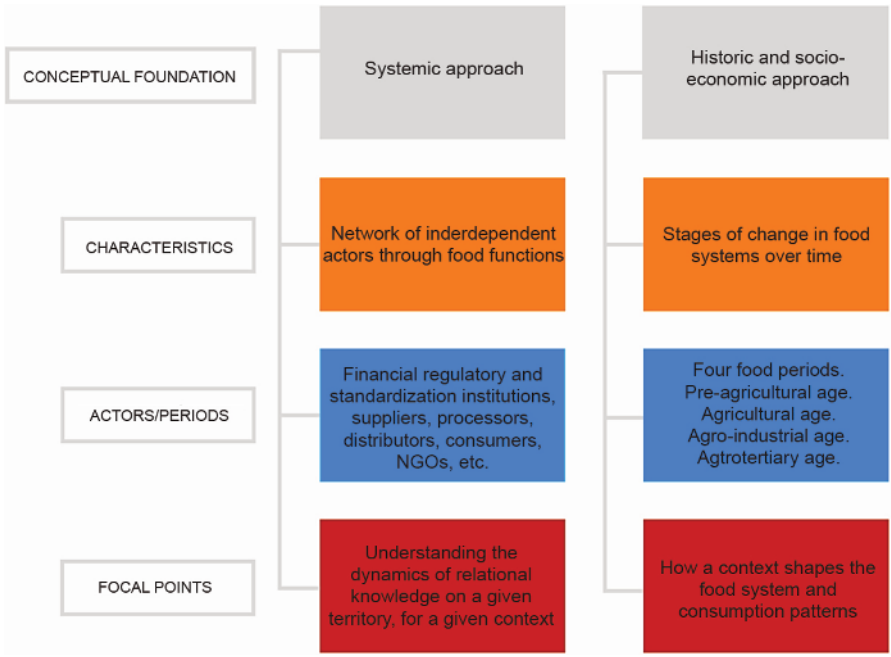

Figure 1.1. *Synthesis proposal on the two conceptual approaches to the study of food systems. For a color version of this figure, see www.iste.co.uk/yannou/ecodesign.zip*

– *The systemic approach* conceives a food system as a network of interdependent actors located in a given geographical space (region, nation, multinational space). These actors participate, directly or indirectly, in flows of goods and services oriented towards meeting the food needs of one or more consumer groups, within or outside the focal area. Any modification of an element in this system may result in the modification of one or more other elements. This approach is useful for understanding the dynamics that relational knowledge or specialized and scattered knowledge among different stakeholders (Bengtsson *et al.* 2015) can create. It does

not, however, meet our need here to present a global overview of the major forms of existing food systems in developed countries.

– *The historical and socio-economic approach* highlights the characteristics of the different periods that have shaped the world history of food. For example, Malassis (1994) referred to three main periods or "food ages" that are mainly present in developed markets: the pre-agricultural age (hunting and gathering); the agricultural age (sedentarization of humans, cultivation, livestock) and the agro-industrial age (agriculture based on industrial and commercial activities). This periodization is extended by Rastoin's (2015) claim that we are now in an "agrotertiary" age. In this period, farmers are no longer just agricultural producers, they also provide services related to products or region. In this age, food is, from the point of view of its economic content – no longer simply a material good, but a service-solution to certain problems in particular contexts.

The decreasing duration of each of these periods can be attributed to an acceleration of technological change. In Europe, the duration of the first agricultural era was estimated at 10,000 years, while the artisanal era was estimated at a few centuries, the following agro-industrial era was estimated at less than a century, and the agrotertiary era has only been in existence for a few decades. Reflecting the living conditions of the populations, each of these periods gave rise to a diversity of food systems. However, this apparent linearity of the evolution of food systems is artificial, because these different models can coexist, in varying degrees of relative importance, according to geographical areas. Thus, the development of industrial production does not imply the complete disappearance of handicraft production. Indeed, to understand the diversity of existing food systems, a finer analytical grid than historical trajectories is required.

1.3.2. *Characterization of food systems*

Even though an exhaustive description of food systems is unrealistic, it is possible to draw out their diversity by using a supply chain heuristic. Colonna *et al.* (2011) provide such an analysis in their research. The elements identified can be grouped into three groups of semantic variables as shown in Table 1.2.

The consideration of these variables illustrates the diversity of supply chains and food products that may exist. However, within this diversity, six archetypal food systems can be identified that we outline in the next section.

VARIABLES	CHARACTERISTICS
1. Stuctural variables of supply chains, from raw materials to delivery of products/services	These variables describe the geographical proximity between production and consumption (food miles); the number of intermediate actors in distribution circuits ("short circuits" versus "long circuits"); the degree of processing and incorporated service ("raw product" versus "processed product"); the nature of the product, its nutritional values, its food/non-food uses, its preservationn methods; and the concentration of production units.
2. Variables attributable to political or institutional approaches.	The following are taken into account: work organization ("family" versus "wage", "artisanal" versus "industrial"): competition and trade framework; forms of financialization of trade and risk management: the roleand forms of public action (state intervention, local authorities, international institutions); control of the system (direct or indirect support); the international integration or not of the system; governance (control of decisions and information, standardization, approaches through contracts and value chains).
3. Variables that relate to the cognitive processes and social behaviors of the populations concerned by the products and services.	These variables measure the product quality, standards/signs and organizations with which it is associated; the product's relationship to geographical space; the place and legitimacy of technologies (GMOs in Europe); the consideration of people or social justice in production, exchanges and consumption (ethical, cultural or religious dimensions); knowledge and mastery of culinary know-how of food preparation (traditional recipes guaranteed).

Table 1.2. *Characterization elements of supply chains (source: Colonna* et al. *(2011))*

1.3.3. *Historical evolution of food systems: models and functions*

Historically, different food system models have emerged to meet the needs of the various actors in food production and distribution process and the populations dependent on these systems. Figure 1.2 illustrates the major FS models and their global function. Each system is the result of a particular organization and a specific network of actors. Indeed, the industrialization of the agricultural sector and distribution has resulted in the transformation of the food economies in the way of a mass consumption economy (Malassis 1996). This market is made up of an intertwined set of food systems whose respective importance varies according to the

production and import capacities of each country. But this market is also defined according to the standards of living, consumption practices and public expectations.

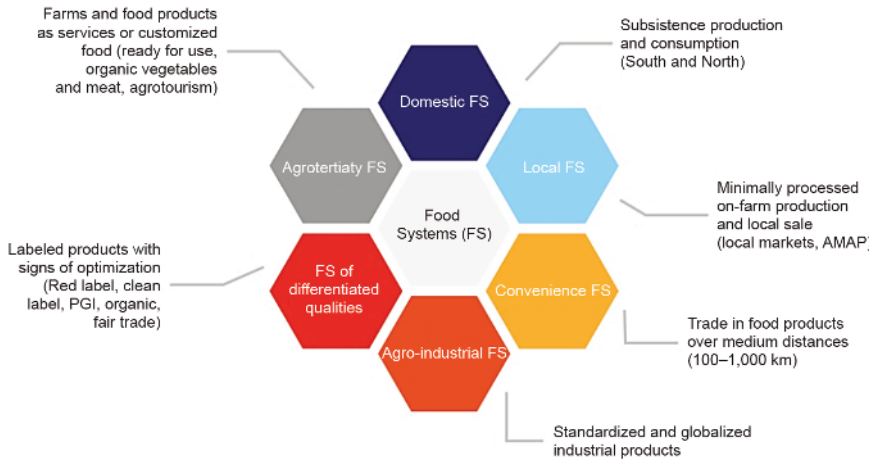

Figure 1.2. *The major models of food systems providing the creation of world food supply. For a color version of this figure, see www.iste.co.uk/yannou/ecodesign.zip*

1.3.3.1. *The domestic food system*

In the domestic food system, processing and consumption are undertaken at the site of raw material production. This system provides for the subsistence of a large part of the populations in poorer nations. Recently, this system has been undergoing a renaissance both in the developed and developing countries and even in urban areas. Its mode of functioning can be organized by an individual, a family or a community through either allotment or plots or shared urban gardens (Scheromm *et al.* 2014).

1.3.3.2. *The local food system*

The local food system differs from the previous one in that it sells all or part of its production. Historically, this FS is present throughout the world, and currently strengthened in the northern countries through the involvement of local communities through local markets, direct sales on farms, consumer associations and/or producer organizations such as the *Association du maintien d'une agriculture paysanne* (AMAP).

1.3.3.3. *The convenience food system or traditional food circuit*

The convenience food system allows the exchange of basic food products (cereals, tubers, pulses, fruits and vegetables) that can be stored and transported over medium distances (100–1,000 km) from production to consumption sites, which are often urban. The main logic that motivates actors in this system (i.e. producers, transporters, wholesalers, artisanal or semi-industrial processing companies and retailers) is to secure the supply and distribution of their production with relatively low material investments.

1.3.3.4. *The agro-industrial food system*

The agro-industrial food system has emerged since the 1950s. It is based on the development of improved transportation and the agri-food industries (AFIs). This system is based on a logic of producing standardized food at the lowest possible cost with stable quality for mass markets.

The objective of this type of system is to take advantage of economies of scale to reduce production costs and thus the final cost to the consumer. This system has led to a decrease in the share of the household budgets devoted to food. This has made it possible for consumers to spend on other items, including education, housing and recreation. Thus, the share of the budget of French households devoted to the purchase of food and beverages (alcoholic and non-alcoholic) fell sharply from 34.6% in 1960 to 15.1% in 2016 (Bourgeois 2017). This industrialization replaced artisanal farmers' knowledge with scientific and technical knowledge, nearly all of which is developed outside farming. With the globalization of markets, dominant players (manufacturers or distributors) have emerged. These actors can often define the required quality of the farm output and impose it as a standard (Humphrey and Memedovic 2006). Paradoxically, even though this standardization ensures the stability of food characteristics and guarantees food safety, it also contributes to a reduction in the diversity of agricultural practices and biodiversity. Finally, it is predicated on the use of chemical inputs to ensure the required productivity (Meynard *et al.* 2016).

For this system to develop, two prerequisites were essential: the ability to preserve and store food to ensure its year round availability. The two major innovations that made this possible were (Soler *et al*. 2011):

– *the development of preservation techniques* such as some food preservatives and refrigeration systems. These techniques encouraged the development of abundant supplies, especially of ultra-fresh and dairy products. It also contributed greatly to the deseasonalization of the fruit and vegetable supplies;

– *the use of various* preservatives that ensure that the desired properties of the food product are *consistent*.

The evolution of the general principles on which the contemporary food industry is based has been made possible by the dissociation of two stages in the transformation process (Soler *et al.* 2011):

– the refining of agricultural raw materials in such a way as to extract their elementary components;

– reassembly, which is the process by which food is reconstituted from these elementary components to constitute a recipe.

This deconstruction/reassembly dynamic is at the heart of industrial processes for processing and preserving food products. The purpose of this dynamic is to modulate the properties of the raw materials to control the properties that are inherent in the processed product (Trystram 2004). The dissociation of the stages of the transformation process has resulted in the emergence of two types of companies:

– manufacturers of intermediate food products (ingredients, additives and technological inputs), whose main research and development activity is focused on improving cracking processes, i.e. the reduction of complex organic molecules into smaller ones or ensuring that the desired properties of the final products are achieved;

– assembly manufacturers, whose innovations have focused on developing new products, thereby considerably expanding the range of products available to consumers.

In Europe, the food supply from agro-industrial food systems now confronts societal demands in certain markets. These demands include, for example, the reduction in meal preparation times due to women entering the work force and the increasing proportion of single-parent households. In France, increased urbanization has resulted in shorter meals and demand for practical, almost tailor-made meals (Madella 2018). Thus, to accompany these new lifestyles, food is becoming more and more functional as expressed in the saying “we eat as we live”. Simultaneously, growing concerns about the impact of food production on the environment and its consumption on health are pushing the evolution of food systems (Kantar TNS study conducted for SIAL 2016). In this regard, the European Commission points out that “urban planning and management” and innovations in urban food systems are providing development opportunities in both urban and rural areas, improving food security and countering various forms of malnutrition (De Cunto *et al.* 2017). This is at the heart of current widespread concerns about *how to feed the world’s population in 2050 if two-thirds of the population lives in cities* (FAO 2014).

1.3.3.5. *Food systems of differentiated quality*

The products of these food systems have differentiated identification signs and/or product quality attributes. While these are not on the product, they exist as signifiers of environmental, superior, original, ethical, religious and other qualities. This information is therefore embodied in quality signifiers such as the clean label, fair trade or private brands described as homemade products, traditional recipes, etc. Different production, processing, distribution and consumption systems are involved in the creation of each of these quality indicators:

– *food systems committed to heritage quality*. These systems based on particular regions or knowledge systems (e.g. about production or processing) represent devices for linking food quality to natural particularities or ways of producing the food item. For example, official quality signs such as PGIs (Protected Geographical Indication) in Europe guarantee a strong link between the product and the production conditions of its place of origin. TSG (Traditional Specialty Guaranteed) products certify that a food product has been manufactured according to a traditional recipe;

– *food systems of superior taste and quality*. French products certified "*Label Rouge*", for example, guarantee quality linked to superior production or manufacturing conditions, varieties or breeds;

– *food systems linked to the natural attributes of agricultural or livestock practices.* Product quality is based on environmentally friendly, energy-efficient practices and the people involved in production. These include organic farming, sustainable agriculture or permaculture. These systems can incorporate various values such as environmental protection, food safety through the absence of synthetic plant protection products, animal welfare, ecosystem, biodiversity, etc., that consumers consider important;

– *food systems with ethical, religious or community quality*. Here, the product's quality is derived from these systems, such as fair trade, kosher and halal. These are based on practices and organizations that respect moral or religious values and/or solidarity with a category of people such as small producers in the South, people with disabilities, or members of a religious faith.

1.3.3.6. *The agrotertiary food system*

The agrotertiary system has been developing since the end of the 20th Century. While the increased demand for services changed the definition of supply in its agro-industrial production and dissemination stages, it had also changed consumers' and producers' expectations of agricultural production stages.

This evolution suggests that now agriculture has a new market logic that defines new competition between producers and is based on new concepts and methods adopted from the tertiary sector. This tertiarization appears in three ways (Lorino and Nefussi 2007):

– *farmers have become providers of market services*. For example, they are involved in the development of green tourism (catering, accommodation, etc.);

– *farmers become non-market service providers*. Here, they are recognized as providing landscape management, land use, environmental preservation, etc.;

– *the tertiarization of agricultural production*, providing a "product-service" can mean making raw products available in places close to where consumers live (vegetable baskets at the exit of the subway, at the workplace, etc.) or undertaking initial processing on the farm. This includes producing soups or preserves, butchering fresh meat and vacuum packing, and a myriad of other products/services.

With agricultural sector tertiarization, value creation methods within food chains are changing and becoming more complex (Lorino and Nefussi 2007). This tertiarization suggests reexamining the modes of creating and sharing the economic value created. The addition of a service to the agricultural product allows farmers to increase the value of the product, but also transforms the farm's economic model.

Food processing requires premises that comply with the health regulations. This implies investments in equipment and training, but also requires operators to find time to produce, promote and distribute their products.

Similarly, the creation and implementation of biogas plants, linking local authorities, food distribution stakeholders and farmers, reexamine the nature of the value created by the agricultural producer and the definition of his/her profession.

Finally, the multiplication of data capture applications, the compiling and processing of crop and livestock data, including data on land conditions, reactions to animal and land treatments, etc., provide new sources of value creation. Food actors are therefore confronted with new service challenges related to the digitalization of the agricultural and agri-food sector. Digital technological innovations can be used to develop new "sustainable" solutions to decision-making processes. For example, by providing a better knowledge of plots and crop needs, precision agriculture makes it possible to reduce inputs through the more precise use of seedlings and treatments (use at the right time, in the right dose, etc.) and thus reduce environmental impacts (PwC 2016). Through these innovations, the added value of agricultural and food technologies becomes less linked to the tangible aspects of the machines themselves and more linked to digital services that accompany them. Today, almost all machines have sensors that collect data not only on their own

operation, but also on the environment in which they operate (Zysman and Kenney 2018). Indeed, these machines, ranging from feeding stations and dairy farm milking machines to tractors and machines for sowing and field harvesting, can detect, collect and transmit data to databases where the information can be processed and presumably result in greater efficiency. To achieve their optimal service efficiency – for economic actors and for the environment – the use of these technologies will require new working and organizational methods, new skills that will be accompanied with greater processing of information flows. While these digital innovations offer new opportunities for agri-food system actors (improved operational function, prediction of risks, etc.), they nevertheless change skill requirements, such as an ability to use software and analyze output, and change employment and employability. These may change the role of farmers in this transformation of the organization of work in agricultural, food and distribution enterprises.

These new organizational forms in the agricultural world are emerging and changing the existing order in response to the expectations of public and societal policies. This requires firms, which are dependent on consumer confidence, to create innovative or customized food products, introduced as "solutions" compatible with the new requirements. This means the development of products that meet current values, including respect for the environment, improved animal husbandry conditions, and the enhancement of the production area of agricultural products.

1.3.3.7. *Conclusions about the co-existence of food systems*

The different elements that interact in the creation of food systems and the multiple values of the products/services they create show that the food function and its challenges have been constantly evolving since the sedentarization of man. The evolution of these food systems illustrates a shift from a traditional food system producing low-processed food products of high heritage value to one in which food products of pre-specified (standardized) quality and in which the definition of the proposed food product is characterized by an approach of building the problem/solution pair that is always renewed (HLPE 2017). This renewal is made possible by the active integration of consumer needs and societal requirements into food product design and innovation which improves an existing product or creates a new one. In this model solutions are, at least in part, co-designed, co-produced and implemented by the various actors in the food value chains. These solutions are increasingly the result of collective action by various parties and undertaken with the goal of creating a more sustainable food supply. However, if there is indeed a time frame for the emergence of these different systems, one of the factors contributing to the complexity of this economic sector is the coexistence and intermingling of these different systems. Coexisting in varying proportions according to geographical areas, needs, cultures and wealth of local populations, the systems respond locally to

the expectations of different socio-economic groups. One of the questions raised by the desire to integrate sustainable development into the overall food system is how to understand the balance required to maintain between the variety of systems and the types and organizational forms that the current digital revolution should enable and that could meet current and future global challenges, and how this could occur, while respecting the know-how of businesses involved in developing the food supply.

1.4. Evolution of food: disruptions in the practices and symbolism of foodstuffs

Section 1.3 introduced the organizational archetypes of major food systems and the objectives to which they respond. In this section, we describe how changes in the practices and paradigms of the various stakeholders have made it possible to transform these systems and change the very nature of food.

The evolution of food is understood in the light of the changes that society has undergone as a result of the industrial and agricultural revolutions. The industrial revolution, a consequence of the discovery and exploitation of fossil fuels, has totally changed the role of physical labor and the scale of food production and processing. This industrial revolution has transformed agriculture and changed not only production, but also the functions and value of food. The mechanization of agriculture, the intensive use of fertilizers and pesticides, and progress in the processing, packaging, transport and marketing of agricultural products have all contributed to and been the result of the emergence of an agri-food industry. All of these developments coevolved with changes in consumer demand and societal needs.

The food evolution has taken place in a context of growing populations and wealth. An increasing number of innovations of functional food have been accompanied by the development of these riches. This process of "industrial capitalism" (Cohen 2006) manifested itself through six revolutions or disruptions (see Table 1.3): in agricultural production modes (see section 1.4.1), business organization (see section 1.4.2), agricultural food processing, land use and development (see section 1.4.3), distribution (see section 1.4.4), consumption (see section 1.4.5) and in the identity and value of food products (see section 1.4.6).

EVOLUTION OF FOOD SYSTEMS	TRANSFORMATION OF AGRICULTURAL AND AGRI-FOOD PRACTICES
Disruptions in agricultural production modes	Standardized agricultural raw material. Digital management of agricultural work.
Disruptions in the ways companies are organized	Mechanization of production units. Standardized management systems.
Disruptions in the ways in which space is occupied and developed	Transition of food production from the farm to the sectors. Agricultural spaces as lands of geographical denomination and know-how
Disruptions in distribution systems	Proliferation of food and non-food products inhypermarkets. Concentration of distribution and development of distributors' private labels.
Disruptions in consumption patterns	New models for the organization of consumption. (procurement practices, preparation, consumption). Search for new meanings to food functions.
Disruptions in the values carried by food	Development of health foods. Development of new food design skills.

Table 1.3. *Relationship between changes in food systems and in agricultural and industrial practices*

We next discuss these different disruptions and show how technological advances in the food system are related to increased knowledge about food, its components, changes during storage, mechanisms for controlling desirable or undesirable biochemical compounds and processes, all of which have contributed to the enhancement of food quality and safety. We then reflect on the positive and negative consequences of this progress.

1.4.1. *Disruptions in agricultural production modes*

During the 20th Century, cultivation and livestock farming methods in developed countries underwent a major transformation. Extensive animal husbandry practices (open-air grazing), in large part, have given way to intensive animal husbandry. Thus, of the 60 million hens raised in France, only 5 million live outdoors. Globally, industrial livestock farming produces 74% of the poultry meat, 50% of the pork meat, 43% of the beef and 68% of the eggs consumed[2].

2 Source: www.donnees-environnement.com/chiffres-agriculture.php#france.

Agricultural raw materials have gradually become standardized in order to limit the impact of production hazards on the quantity and quality of products intended for industry. At the same time, the globalization of raw materials flows has broadened the sources of supply for factories and dispersed agricultural and food flows in an increasingly complex and intertwined system of international trade.

The transformation of agricultural inputs and outputs and livestock through genetic selection practices has led to a reduction in the number, diversity and variability of agricultural raw materials over time (see Figure 1.3).

The standardization of the characteristics of raw materials facilitates the productivity of industrial processes and the stability of the performance of processed products, but reduces the variety of agricultural supply. However, the reconstruction of product variety at the industrial level, precisely at the assembly stage, increases the diversity of finished products, introducing delayed innovations as an important feature of the dominant food system (Trystram 2012).

However, the evolution of the supply of food systems is not only driven by technological innovations. As mentioned in Table 1.2, societal demand is also responsible for the increase in the number and change in the nature of the quality criteria for defining a foodstuff.

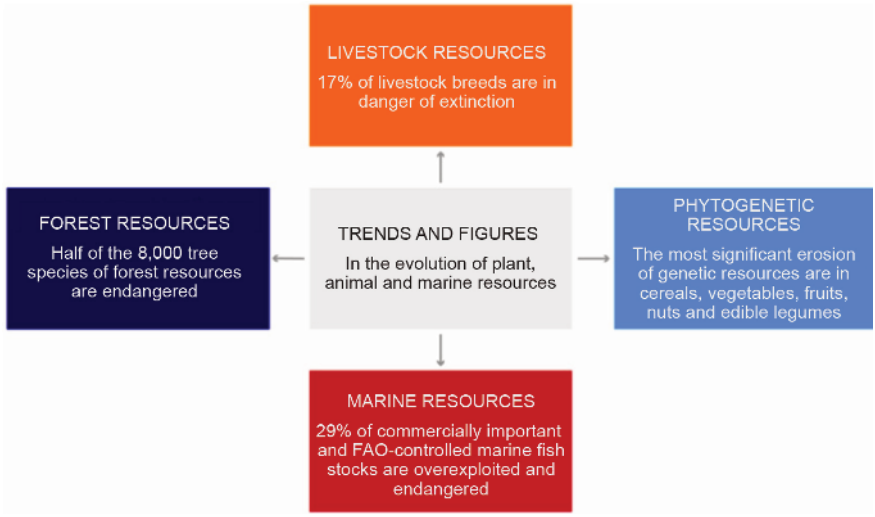

Figure 1.3. *Trends and figures in the evolution of agricultural practices and livestock (source: FAO 2014a). For a color version of this figure, see www.iste.co.uk/yannou/ecodesign.zip*

To better analyze the quality of a food product, Barbosa-Canovas *et al*. (2009) propose eight variables:

– sensory and organoleptic components;

– nutritional components;

– safety;

– cost;

– practicality, including food stability and preservation;

– the image linking the product to a landscape, a culture;

– environmental protection, sustainable agriculture and organic farming;

– ethics, as occurs with, for example, the development of fair trade products.

The wide range of solutions made possible by the intersection of all these characteristics sheds light on the complexity of food product design. This complexity is reinforced by the variability in the final consumer's perception of their culture, previous experiences, timing and tasting conditions (Eckert *et al.* 2014).

The evolution of food supply over the past century, which has led to the multiplicity of these criteria, is illustrated in the French context by Figure 1.4 resulting from the work of Colonna *et al*. (2011). The latest development is the rise of concerns about the sustainability of food systems. This concern has led food production stakeholders to reengineer their previous criteria to make them compatible with the principles and challenges of sustainable development.

The technical constraints of the processing industries require, on the one hand, stable properties in raw materials and, on the other hand, compositions appropriate to the physico-chemical reactions they must control (e.g. a high gluten content of wheat for baking). These constraints have pushed agricultural production towards specialization and standardization. This standardization has moved innovation spaces to transformation, where new recipes are created. The value-creating factors in this area were initially far removed from the quality of the material itself. Then there were, questions on the impact of material quality on consumer health, and then finally on nature and society.

1.4.2. *Disruptions in the way companies are organized*

Initially, the craftsman was replaced by the factory operator; then the number of the latter decreased due to the mechanization of production. The loss of knowledge, know-how and responsibilities of the operators of these successive organizations has

made it necessary to invent new forms of management. They address these knowledge gaps and propose hierarchical structures that establish shared responsibility. This is the challenge of Taylorian and Fordist forms of labor organization.

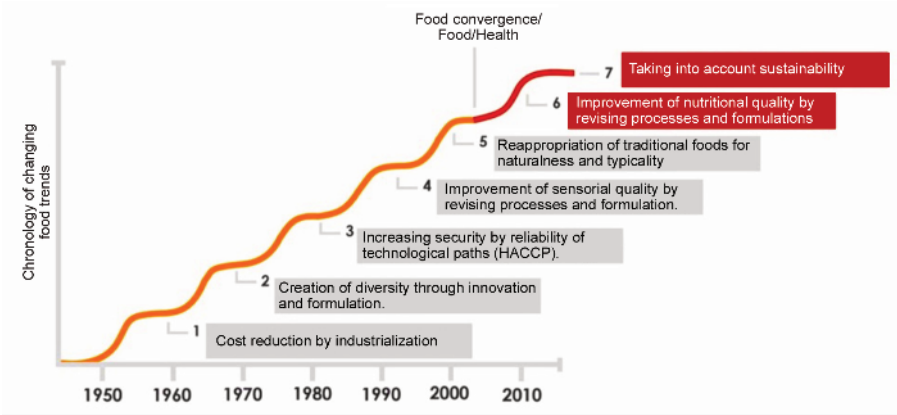

Figure 1.4. *Historical evolution of factors explaining the evolution of food quality (source: Colonna* et al. *2011). For a color version of this figure, see www.iste.co.uk/yannou/ecodesign.zip*

In France, in the middle of the 19th Century, following problems of falsification and fraud affecting certain food products (wine in particular), regulatory frameworks developed with a dual objective of disciplining competition through economic regulation and protecting consumers through health regulations. Indeed, in terms of consumer health regulation, the government no longer controls the quality of the processes of transformation, as this role has been transferred to the producer of the product (Stanziani 2005). There, the producer must ensure that the processes guarantee safety.

For companies, these regulatory frameworks, although often perceived as constraining and costly, have provided training and learning support for their staff. This contribution was further reinforced by the implementation of Total Quality Management [TQM]) principles (Juran and de Feo 2010).

At the end of the 20th Century, food quality control and assurance were integrated into organizational management practices as a new source of business value. The deployment of quality management system standards (the ISO 9001 family) has become widespread in agri-food companies and craft workshops, thereby playing a major role in the dynamics of these organizations and increasing the value of food products. Indeed, by supporting continuous improvement loops,

the type of management linked to these normative approaches allows the development of the company's dynamic capabilities (Teece 2007). These dynamic capabilities represent the company's ability to identify new needs and opportunities and to seize and transform its practices and culture to meet new needs through relevant innovations. This transformation involves the integration, into the organizational structure and production processes, of new knowledge (related to technologies, processes, supplies, including the expertise of external stakeholders) that complements and reconfigures the elements of its business model.

The shift from artisanal to industrial food production has distanced the end user from the raw material producer. This distance implies a transfer of responsibility, as the processor becomes the guarantor of the level of hygiene of the product. To ensure this result, public policies have established a regulatory framework that ensures the health and safety of production and thus consumer protection. This regulatory framework his complemented by a normative framework, based on good practices, the implementation of which can have two effects. First, the application of standards provides certain factors that differentiate the product offering and include compliance with rules regarding the product's safety. Second, management system standards are a potential source of questioning established practices, and encourage the analysis of new stakeholder needs; in this sense, they constitute a lever of innovation for the company (Serhan 2017).

1.4.3. *Disruptions in the ways in which space is occupied and developed*

By moving away from their initial status as food producers, consumers have changed their eating habits, while having an increasing concern about their food. They no longer know the history of the product they consume, feel they have lost control over the quality of their food and consequently question their trust in the food industry in general and in food brands in particular. These concerns have been fuelled by various scandals and journalistic investigations.

Fischler (2004) distinguishes two categories of changes that have occurred since the 1950s that have contributed to the evolution of Western eating habits:

– general changes (social and demographic factors, etc.) have impacted the use of the agricultural space in Western European countries. In the 1950s, a quarter of the French population lived off the land or in the countryside. Between 1980 and 2007, the active agricultural population in France dropped from 8 to 3.4% of the total active population (Agreste 2011). Between 2010 and 2013, the number of farms fell by a further 8% from 490,000 to 450,000 (INSEE 2015). Moreover, agricultural activity no longer depends on all family members, as farmers' spouses are increasingly working off farms (Agreste 2012);

– Changes, specifically in relation to the field of food, have influenced the diet and sense of the function in industrial countries. Food has become a product processed by industry or food services firms and is increasingly consumed outside the home. Social categories are also changing as consumers are increasingly from "white-collar" occupations and have different nutritional and service needs from those consumers with high levels of physical activity that constituted a preponderance of food markets in the 1960s.

The development of specific quality food products (AOP, PGI) has addressed some of these concerns. These products, which are based on a region, have enabled producer groups to differentiate themselves by reserving names (mainly geographical) associated with "products of origin" whose specificity is linked to local production conditions (geology, climate) and related heritage (traditional know-how). However, over the past 20 years, the differentiation function played by appellations of origin and food certification has become less predominant. This is because of the establishment of private label products that have the advantage of referring to the locations, but also have lower prices (Lagrange and Valceschini 2007).

The increasing urbanization of populations has intensified the extent of the gap between agricultural production and consumers. In parallel urban lifestyles, changes in household composition and the increase in employment among women increased consumer demand for processed food despite the concerns they have about such foods. The development of registered designations and quality labels is an attempt to address these concerns and create products with higher added value. And yet, the multiplication of such quality signs has, in recent years, blurred their meaning and reduced their effectiveness with consumers.

1.4.4. *Disruptions in distribution systems*

The evolution of food distribution methods has accompanied the industrialization of the agri-food sectors. The distributor, with their central purchasing offices, has established itself as a key intermediary between producers and consumers. Their prevalence is reinforced by the information asymmetry that exists between the producer and the consumer and by their financial power during price negotiations. In addition, the development of transportation, ingredient and food preservation techniques have made it possible to provide year-round access to a wide variety of foods, exotic or not. In France, for example, between 1958 (when the first supermarket appeared) and 2001, the number of hypermarkets increased by a factor of 100. These hypermarkets introduced three major changes in food distribution: self-service, low prices and "all under one roof". For example, with Carrefour, in 1963 the hypermarket began offering food and non-food products and petrol

pumps in its parking lots. Today, in France, distribution is dominated by six players that have captured more than 80% of the market with sales in 2011 of 166 billion euros (Eurogroup consulting 2012 study).

The concentration of distribution and the development of in-house brands have changed the balance of power between distributors, processors and agricultural producers. The economic pressure imposed by the distributors on the processors increasingly affects the raw material producers. Indeed, in France, upstream differentiation (supply marketing) has given way to downstream differentiation (demand marketing), i.e. a personalized service offer according to consumers' expectations and needs. In "downstream marketing", the strategies of the commercial brands, under the pressure of requests for price reductions from distributors, have invested even more in promotions. The excessive use of such practices has led to a decrease in food prices. Thus, IRI data (Puget 2018) shows continuous food price deflation of food in the French market between January 2012 and January 2017.

In response to this business model environment, both agricultural producers and processors have sought ways to circumvent this distribution system. This is the case, for example, of the development of "short-circuits", which are associations of producer-sellers that market at physical sales points or on the Internet, and the development by agricultural cooperatives of brands of processed products sold in supermarkets or in their own retail outlets. The Internet distribution system for Nespresso coffee capsules illustrates the alternative solutions sought by the major brands. Finally, it is now the US Internet giants (GAFA)[3] that threaten these distribution systems. For example, Amazon in the United States or Alibaba in China offer food distribution services with fast ordering and delivery solutions such as Amazon Dash buttons.

The development of mass distribution has allowed access to a multiplicity of food products and has democratized the consumption of products hitherto reserved for specific social classes and/or special events. In parallel, the "trivialization" of access to food and the distance between production and consumption on which it is based may have contributed to a form of "devaluation" of food for some consumers. Promotional practices in distribution such as a customer appeal policy have reinforced this trend and have resulted in increasing price pressure. The ultimate impact of these pressures is decreasing purchase prices for agricultural raw materials. As a result, alternative models have developed over the past 10 years. These include short circuits and in-house brand distribution systems. The development of Internet sales is now challenging all of these distribution systems and forcing consideration of multi-channel systems in order to reach all markets.

3 GAFA: Google, Amazon, Facebook, Apple.

1.4.5. *Disruptions in consumption patterns*

The rise of mass retailing has largely contributed to the evolution of consumption patterns, i.e. the way we organize ourselves to consume. But it has also changed the nature and amount of food we eat. These consumption patterns include the organization of the socio-economic unit of consumption (family), the functions of this unit (supply, storage and meal preparation), food practices (culinary systems and food intake) and table manners (culture and society) (Malassis 1994). Several distribution and marketing strategies contributed to this evolution (Étude Eurogroup Consulting 2012):

– *convenience coupled with diversity of choices*: stores are closer to urban areas and offer food and non-food;

– *controlled hygienic safety* as mass distribution is undertaken under standards and hygiene rules (HACCP: Hazard Analysis Critical Control Point), which improves product quality and safety;

– *the democratization of economic access to products for various social groups* as stores increasingly stock luxury products, such as salmon and foie gras, and also exotic products, such as sushi and salsa. There are also first-price or private-label products.

While households are spending an ever smaller proportion of their budget on food, this is also changing. Consumption of fruit and vegetables, breads and cereals meat, and alcoholic beverages is decreasing, but the consumption of processed and sweetened products, as well as ready meals is increasing (INSEE 2015).

However, some consumers have become aware of the effects of the industrial production and consumption model on global warming, depletion of natural resources, nutrition and health and social inequalities. This awareness is now driving food system actors to search for alternative business models to provide new meaning to food and new values for food. These new expectations regarding food supply have prompted some agricultural producers and some agri-food industries to adopt new innovative strategies to enhance the value of their products through new production techniques valuing nutrition and health, respect for the environment, humans, biodiversity and land.

Supermarkets with an abundant supply of both food and non-food products have changed our consumption patterns. Awareness of the effects of industrial production on natural resources, the environment and the social factors involved in the food chain is driving some consumers to demand products with ethical and ecological characteristics that are superior to what has been previously offered.

1.4.6. *Disruption in food values*

In developed countries in the 1980s, to give products an identity compatible with the search for a positive impact on health, the concept "healthy food" was introduced. These "foods" were meant to create a new form of value for food by contributing to the eater's health.

The role of food is no longer only to nourish and provide the calories required to satisfy metabolic functions. It should provide the right nutrients to prevent disease or delay aging; something particularly important in societies where self-image is becoming increasingly important. Such a perspective fundamentally transforms the objectives of food product design, transforming it from the "pleasure food" rationale characteristic of the traditional French culinary model to a "healthy food" rationale that was adopted in the English-speaking countries. This nutritional model, which also experienced success in Asia, has struggled to be accepted in France.

Despite the French market's reluctance to accept such health foods, certain functional foods, aimed at a specific health function, have been commercially successful. Actimel is an example of these successes. This product is fermented milk enriched with probiotics and vitamins marketed as a food that strengthens the immune system. Cereals fortified with oat bran fermented with lactic acid bacteria beneficial to the intestinal flora or margarines fortified with vegetable stanols to lower cholesterol levels are other examples of functional/customized foods associated with specific health objectives. However, in France, these health-oriented innovations are often perceived as "unidentified edible objects" (Fischler 2001). While some consumers have acquired the necessary nutritional knowledge to take an interest in these new products, others have not accepted them either due to lack of knowledge and/or refusal to eat foods perceived as unnatural (Lagrange and Valceschini 2007). However, demand for natural food has grown in the 21st Century. A desire for "just food" (Padilla *et al.* 2005) has grown among some consumers in search of authentic products whose origins and/or manufacturing processes is known. These are products that the consumer believes express who they are and, as such are singular (Camus 2004). They are characterized by the naturalness of their ingredients (organic farming, ingredients with little processing, etc.) and are believed to contribute to the health of their eaters. The raw and processed products from the Bleu-Blanc-Cœur sector containing omega-3 rates higher than those on the market illustrate the products that have been accepted and valued by this market. In this case, the omega-3 content is not due to a "fortification" of the food *a posteriori* (such as certain milks that can be fortified with iron), but due

to a modification of the animal feed thanks to the addition of flax in its food. This practice, for the majority of consumers, does not contravene their desire due to the "natural" animal feed practices.

In this new competitive context, the challenge for companies no longer lies solely in the speed of creation and market access obtained through "continuous innovations" (Deschamps and Nayak 1997; Verona and Ravasi 2003), but rather in their ability to thoroughly review the functionalities and expertise required to design a product/service adapted to and valued by the society needs (Acquier 2007).

To do this, companies must develop new practices that allow them not only to open up to their environment, but also to experiment internally (Achtenhagen *et al.* 2013). These practices were defined by Chesbrough and Brown (2006) as open innovation. This "open or distributed innovation" model recognizes the advantages of relying on the access and use of expertise and technologies developed by several external actors in order to produce, in our case, food products of societal interest. The value of the innovations resulting from this model is linked to the company's ability to learn and absorb external and specialized knowledge to complement internal knowledge and to increase the value or functions of a differentiated product offer.

In a sustainable development framework, food innovation could be a "mutually beneficial" learning process between the food industries and their stakeholders. By integrating the needs and skills of different external stakeholders into the management strategy and practices (vision, mission, business models), the companies tend to "manage society", i.e. introduce the management needs of the company into new spheres such as public institutions, academic research and standardization bodies. And by demanding food innovations from manufacturers that meet the principles of sustainable development, society (consumers and stakeholders, the environment) tends to "socialize management" (Acquier 2007), i.e. systematically integrate social dynamics within management (well-being, health, environment, etc.).

To meet the expectations of a part of the society in which they operate, companies are engaged, through a transformation of their practices (speeches, tools and methods), in innovative design, symbolic communication and awareness-raising efforts. These facilitate the acceptance of the company's innovations by target consumers. These innovations tend to "manage the society" and are continually enriched by societal transformations and new requirements to create value.

CHARACTERISTICS	SIGNIFICANT ASPECTS	NEGATIVE IMPACTS	LIMITS FOR THE ENVIRONMENT	CONTRIBUTION TO GLOBAL FOOD SECURITY
Intensive agricultural and industrial practices	Technical innovations (very high yield per hectare, in factories and per worker) Delayed innovations (fractionation/assembly) Creation of new sectors (packaging, logistics, distribution, catering) Reduction of food price High health security	Intensive use of chemicals on the farm, over-use of antibiotics and hormones	Massive increase in greenhouse gas emissions Water pollution Soil degradation Decrease in farmers' incomes Loss of producers' self-sufficiency Disappearance of bees	Physical availability of food: quantitative food security (supply side) is ensured in Western countries and there is still need to reconsider population growth by 2050 "Sufficient and safe food"
Specialized production and processing basins	Controlling hazards (climate, price) by standardizing a limited number of plants and animals	Erosion of agricultural and food biodiversity More fatty, sugary, and meaty foods	Erosion of agricultural and food biodiversity More fatty, sugary, and meaty foods	Food use: Diets are not diversified Foods lose a lot of nutrients Nutritional transition inducing diet related chronic diseases "Non-nutritious food"
Sector concentrated upstream and downstream	¼ of farmers provide ⅔ of agricultural production 10% of companies provide ¾ agro-food industry turnover Mass distribution is handled by 6 stores	Unequal distribution of value added in the agricultural and agri-food sectors	Economic viability of agricultural producers and of future supply at risk	Economic security of farmers in impoverished developing countries that have less competitive agricultural production. "Irresponsible feeding at the socio-economic level"
Financialization	Agro-industrial leaders are listed on the stock exchange	Shareholders demand short-term profitability	Different governance models (large groups, family businesses and cooperatives).	Economic security poorly distributed among economic agents (increase in revenue for industrial groups to the detriment of small agricultural and agri-food producers). "Unbalanced diet"
Globalizing agro-industrial model	Increasing direct investments abroad (Carrefour has 12,300 stores in more than 30 countries) Intensive international trade	Relocation of activities to countries with costs advantages Long distribution circuits Transport pollution Nutritional transition; more meaty, fatty and sugary diets	Loss and waste during transportation	Increase in food availability in some developing countries (globalized network for processing and distribution of standardized products). "Global food with no typical flavors".

Table 1.4. *Impacts of the agro-industrial food system on food security and the environment. For a color version of this figure, see www.iste.co.uk/yannou/ecodesign.zip*

1.5. Contribution of food systems to food supply

Since the middle of the 20th Century, leveraging scientific, technological and organizational innovations that have promoted the productivity and competitiveness of agricultural and agri-food products, the agro-industrial food system has responded to the desire to improve Western countries' food security. It diversified the products available, provided larger quantities and supplemented nutritional intake, while offering an increased range of services adapted to social needs. However, the evolutionary trajectory of this system has also revealed negative impacts, affecting social, ecological and nutritional aspects at each phase of these changes. Table 1.4 summarizes not only the positive and negative aspects of the agro-industrial system, but also its impacts on food security and the environment.

1.5.1. *An intensive, specialized and concentrated agro-industrial system*

The upstream and downstream standardization practices and intensive livestock farming methods have increased agricultural and industrial productivity. And yet, these practices have been responsible for serious environmental, social and cultural damage that threatens the ecosystem, biodiversity and dietary intake. Today, 75% of agricultural biodiversity – the variety and variability of plant, animal and micro-organism species used by farmers – has disappeared in the last 100 years (FAO 2018). There are many other indicators that highlight the damage to biodiversity. For example,

– of the 30,000 edible plants, 7,000 are grown or harvested by humans for consumption. Five cereal crops (maize, wheat, rice, barley and sorghum) provide 60% of the world's population with energy;

– of more than 30 species of farmed mammals and birds, 90% of the farmed products for consumption are provided by only 14. In fishing, many species are on the verge of extinction due to overexploitation;

– 31% of the yield reduction in plots of less than 2 hectares is linked to the disappearance of bees and other pollinating insects (Vaissière *et al.* 2011).

Food, initially considered as a vital and cultural product, has become an industrial and market (or commodity) good. The leaders that control the modalities of its production, processing and distribution are listed on the stock exchange and pursue short-term growth and profitability objectives even as they offer increasingly inexpensive food products. Moreover, the strong concentration of distributors' buying groups unbalances the distribution of added value within the agricultural and agri-food sectors in both northern and southern countries (Reardon and Timmer 2007). However, the possible decline of agricultural productivity with the effects of climate change and soil depletion suggests that the trajectory of food systems is likely to lead to an increasingly expensive food supply (Timmer 2017).

1.5.2. *A globalized agro-industrial food system*

Improving physical and economic access for all consumers to a wide variety of food products is one of the pillars of food sustainability (FAO 2015). However, the negative impacts of supply globalization on the other pillars of sustainable food development, in terms of environmental, social, and nutritional factors, have been highlighted in various studies (Timmer 2017; Fournier and Touzard 2014; Rastoin and Ghersi 2010; Reardon and Timmer 2007). To illustrate,

– at the environmental level, international trade in food increases the distance (food miles) between sites of production and consumption. As a result, internationalization increases greenhouse gas emissions and other externalities in the transportation sector, which is responsible for moving goods and providing services between countries (OECD 2011);

– at the social level, by investing in foreign countries with better opportunities, foreign investors may cause crises in local financial markets (Reardon and Timmer 2007);

– at the nutritional level, the proliferation of supermarkets in emerging countries facilitates the diffusion of new products that stimulate demand while disrupting pre-existing diets. As a result, current diets are increasingly migrating to meat and sugar- and fat-rich diets, which are responsible for several diseases related to poor nutrition (HLPE 2017).

The analysis of the historical trajectory of food systems carried out in this chapter shows a coexistence between a dominant globalized agro-industrial system and alternative food systems. Even though some of these alternative systems have existed for a long time (e.g. short circuits or proximal circuits), others are increasingly reacting to the limits of the current industrial models. A report of the High-Level Panel of Experts of the Committee on World Food Security classifies food systems into three groups and identifies their associated food scourges (HLPE 2017):

– *traditional food systems* that provide unprocessed seasonal products highly dependent on rural sources with heritage value. These suffer from the highest prevalence of undernutrition which includes, stunted growth, wasting infant mortality, etc., and the highest rate of micronutrients;

– *mixed food systems*, with the traditional model and mass distribution, within which all forms of malnutrition coexist;

– *modern food systems* providing healthy, diversified food products sold in stores or prepared food outlets that are characterized by the presence of structured and easily accessible markets in high-income regions. However, these systems also have "food deserts" where there is limited or non-existent access to food and "food quagmires" with an overabundance of unhealthy food and limited access to healthy food; both of which are characteristic of low-income regions. These food systems

are associated with lower rates of undernutrition and micronutrient deficiencies than traditional food systems, and also have higher levels of obesity.

In a context of developing a sustainable food supply, this cohabitation between the agro-industrial system and alternative systems promotes food security and innovations in the agri-food chain (Fournier and Touzard 2014). These innovations provide a new definition of supply chains, namely environments that offer consumers the opportunity to build new forms of consumption in which the negative impacts of value chains can be reduced.

Taking into account the negative impacts of agricultural production and food processing methods has been a subject of much political, economic, sociological, nutritional and academic research and debate in the several decades. This raises concerns about the future of the global food system. But the development of an actionable agenda that takes into account the interests of the various stakeholders in the food system and the planet remains complex. Proposals for improving or changing practices remain in the form of trend-based scenarios. For example, the OECD report published in 2016, entitled "Alternative Futures for Global Food and Agriculture", proposes three scenarios for the future of the global food system by 2050 based on three key trends (Table 1.5).

World Food System Scenario	**SCENARIO 1** **"State self-sufficiency in the use of fossil energies"**	**SCENARIO 2** **"Sustainable growth based on citizens' concerns"**	**SCENARIO 3** **"Rapid growth based on globalization and international cooperation"**
TRENDS	Growing and changing food demand.	More constraints on the use of natural resources.	Uncertainty over agricultural yields linked to global warming.
CHALLENGES	Produce diversified foodstuffs in quantity and quality.	Produce respecting the ecosystem.	Adapting to the unpredictable effects of food systems.
PROSPECTIVE BUSINESS STRATEGIES	Growth and self-sufficiency in fossil energy Investments in technologies less dependent on fossil fuel and natural resources.	Informed citizens and consumers demanding sustainable consumption Production agenda for a green society Development of regional and urban distribution/ consumption	Internationalization of sustainable innovative cooperation in practices, tools, processes, processing processes and the supply chain (biofuels, green chemistry, renewable energy, etc.).

Table 1.5. *Trends, challenges and scenarios for the future global food system (OCED, 2016). For a color version of this figure, see www.iste.co.uk/yannou/ecodesign.zip*

1.6. Trends, challenges and scenarios for a sustainable global food system

The challenges of the global food system identified by the OECD (2016) are based on three key trends. These include improving quantitative and nutritional food security; increasing the economic viability of agriculture; preserving biodiversity and respecting scarcity of natural resources; reducing agricultural greenhouse gas emissions and other pollution; promoting healthy diets; stopping the cross-border transmission of livestock diseases; and improving food safety and health.

1.6.1. *Three trends and challenges*

– *Trend and challenge 1: the growing and changing food demand*. The OECD expects further convergence of per capita income between developed and emerging countries given the significant increase in per capita wealth in emerging nations. This should result in a change in the diets of these populations with an increase in animal protein and sugar demands. The challenge here is to produce food for a growing and richer population.

– *Trend and challenge 2: constraints on natural resources*. This challenge focuses on access to natural resources (land, water, fossil energy) that are increasingly limited in order to help mitigate climate change while preserving biodiversity and fragile ecosystems increasingly susceptible to salinization, soil erosion or degradation, deforestation, drought, etc. The scarcity of natural resources could limit the increase in agricultural production and encourage the emergence of risks to quantitative food security.

– *Trend and challenge 3: uncertainty about the increase in agricultural yields due to climate change*. Challenge 3 is to adapt to the unpredictable effects of climate change, which may increase the risks to quantitative food security.

These are immense challenges to the development of effective agricultural and food policies. The industrial strategies to operationalize them have been divided by the OECD into three scenarios that seek to answer the following questions:

– How can the world food system feed nine billion people by 2050 without destroying ecosystems and social cohesion?

– How can agricultural productivity keep pace with rapid demand growth, even as it faces important and unpredictable challenges such as climate change, livestock diseases and other factors that increase production costs?

– Will agriculture be a profitable activity in the coming decades, which can help rural areas to develop and maintain their role in local economies and livelihoods?

These scenarios provide projections or tools for constructive discussion, design and implementation of public and private strategies that are robust enough to address the uncertain contours of the evolution of the world's agricultural and food systems.

1.6.2. *Three scenarios or tools to explore the possible future of the global food system*

– The first scenario, entitled "*Individual, fossil fuel-driven growth*", envisages a growth approach based on individual state decisions and dependence on fossil fuels. It provides for a reduction in agricultural yields due to the intensive use of inputs. Demand for animal protein and processed products will continue to grow without taking into account the environmental impact of meat production and the agri-food industries.

– The second scenario, entitled "*Citizen-driven, sustainable growth*" accepts that consumers will strive to build a "green society" by taking greater account of the environmental and social impact of food production in their behavior. It projects a society where consumers consider the purchase, consumption and end-of-life of a food product.

– The third scenario, entitled "*Fast, globally-driven growth*" accepts the scope and depth of international cooperation, the efficiency of markets and multinational companies and technological innovation and support for the diffusion of these new technologies. It accepts that there will be a further intensification of agriculture and a standardization of food products worldwide around a meat-rich diet.

If the challenge that food poses to food systems is how to organize themselves to feed the world's population without harming the ecology (social, economic, environmental and nutritional factors), the previous elements exposed in this book suggest that each of these scenarios can provide only one part of the solution.

– Scenario 1 (state's dependence on fossil fuels) seems relatively profitable for the agricultural world, but the risks in terms of food safety and pollution would be high given the use of very intensive agriculture and low levels of international cooperation.

– Scenario 2 (citizenship attitude and behavior) envisages limiting the risks of depletion of natural resources and increases in pollution. According to the OECD, it would improve food safety and diet-related health problems, while limiting biodiversity loss and greenhouse gas emissions. Nevertheless, it requires significant adaptation efforts on the part of farmers, industrialists and consumers. For example, farmers would be expected to adopt more sustainable production methods, consumers should change their food consumption behavior, and industries and

distributors would be expected to develop new strategies and practices to pursue sustainable development.

– Scenario 3 (globalization and international cooperation) would increase food availability by promoting agricultural productivity, especially in regions where it is competitive. It is also expected that this scenario would increase environmental (climate change and biodiversity) and health risks. This scenario, which is favorable to large producers, has disadvantages for the planet, consumers, entrepreneurs, and local producers.

These three versions show the complexity of developing a sustainable food program or model that strikes the right balance between the interests of the three stakeholders involved in formulating the population's food well-being. As it stands, these programs and models remain limited to provide a vision of the "future of the world in terms of food". They do not consider agri-food companies, interfaces and the central drivers of relationships between the agricultural world and consumers. The growth and development strategies, management and business models of these companies play a significant role in farmers' production methods and consumers' eating habits. Moreover, these alternative versions of the future of agriculture and food do not specify how to achieve the solutions envisaged.

By 2050, climate change and increasing food insecurity will be major challenges for the world's agricultural and food systems. In this book, we do not intend to propose alternative scenarios for the evolution of the food system; these will undoubtedly come up against an impossible return to the food systems of the agricultural or artisanal age and the difficulty of finding a balance between the socio-economic and ecological objectives of sustainable development. While the coexistence of several alternative food systems is an option to ensure that benefits of sustainable food are respected, the functioning of this cohabitation will remain dependent on consumers' purchasing and consumption behavior.

Through this book, we will seek to place ourselves in a more dynamic perspective, centered on the transformation of the practices of the agro-food companies. This transformative dimension of the company – an intense place of rationalization and transformation – is part of its very nature. As Hatchuel (2000) points out: "the company [...] is not a naturally isolable collective and the permanent revision of its borders (physical, legal, human, commercial, etc.) is a condition of its existence".

The sustainable development is a relatively old political statement (it was first introduced in 1987 in the Brundtland Report of the World Commission on Environment and Development). The introduction of its aspects into the field of company management is recent (Acquier 2007). This movement is described as the "managerialization of sustainable development" (Acquier 2007; Aggeri *et al.* 2005).

This organizational change suggests for companies the exploitation of "new areas of organization and collective actions" oriented towards reducing the impact of activities on the environment. This should be accomplished by undertaking actions that are ethically respectful of the various involved social groups. Its development also requires sharing the wealth created, allowing the various stakeholders to benefit from the improved conditions of their sustainability. These actions constitute a set of discourses to raise awareness, and transformations in current activities and the nature and services marketed. This shift towards more sustainable food also requires organizations to acquire new knowledge at each level in food value chains.

In this book, we will focus on management practices that make "sustainable food development" operational for the agro-food companies. This includes the reconfiguration of products/services and the requalification of the scope of activities. This equalization facilitates the emergence of a sustainable food supply. Two strategies challenge the practices of all actors in the food value chain, from the agricultural plot to the end of a food's life: ecodesign and ecoinnovation. Ecodesign is an approach that focuses on the environmental improvement of a system, product or service. Ecoinnovation consists of creating new sustainable business strategies, processes, operations, products and services, market approach and organizational structure. This perspective allows companies to evaluate where significant progress can be made to address major challenges, and anticipate and avoid future risks (Yannou-Le Bris and Ferrandi 2016).

In Chapter 2, using a "practices" approach, we will define the principles of sustainable development, food sustainability and practices that allow a food system to be part of a sustainable food supply chain. We show, on the one hand, how sustainability issues are instrumentalized by tools, methods and standards and, on the other hand, how food sustainability objectives (nutritional, social, ecological, behavioral) are implemented in the operations of a variety of actors in the food chain.

The main challenge of this approach is its contribution to the understanding of the practices and actors that build a sustainable food system, i.e. economically efficient, socially inclusive and sustainable for the planet. It should be sustainable and take into consideration nutritional and health outcomes. It could also be amenable to agro-industrial companies intent upon reconfigurating their business model.

1.7 Conclusion

This chapter aimed to present the evolutions of food systems in order to show the benefits of these evolutions in terms of food security (quantity, quality and price). It was also intended to shed light, without being exhaustive, on the negative impacts of these developments on the sustainability of the dominant agro-industrial food system. This contrast is not meant to be a condemnation but rather a description of the challenges that food actors are called upon to address in order to contribute to the characteristics of the emerging food system.

Historical and socio-economic analysis of food systems in developed countries has shown that there is a coexistence between the dominant agro-industrial food system, which is spreading globally. It delivers standardized food products, while also allowing alternative food systems that offer products with sustainable added value products that have less processing, a supply of raw materials from organic agriculture and/or through short distribution channels or products with high heritage and cultural value (territories, labels, fair trade, ethnic products, etc.). This new system is far more complex than previous systems.

The factors that enabled the construction and continuous evolution of these food systems indicate that the transformation of these systems' practices was made possible by the agricultural and industrial revolutions. These contributed to the improvement of the physical (abundance of products) and economic (low-cost) access to an increasingly urban and affluent population worldwide. But today, however, the awareness of the effects of industrial production on natural resources, the environment and the social factors involved in the food chain is compelling public and private actors to formulate scenarios for the global food system based on consumption trends, and the ecological challenges of production, increasing food demand, decreasing agricultural yields and the need for ecological products.

Global food systems will face a wide range of challenges in the coming decades. These include a growing population requiring more diversified diets, contributing to economic growth, poverty reduction, rural employment and the development of both rural and urban areas. These challenges are part of a context of increased competition for alternative uses. These include natural resources (land, water), while preserving biodiversity, restoring fragile ecosystems and contributing to climate change mitigation. Agricultural practices will also have to adapt to the unpredictable effects of climate change (higher average temperatures, droughts and floods) that increase risks to food security, particularly in terms of quantities and prices of agricultural commodities.

While the evolution of the function of food and the elements of food systems that contribute to its formation can be understood in the light of the changes that French society has undergone, this evolution is continuing today through the digitalization and the encroachment of digital platforms into the agricultural value chain. This digitalization or dematerialization of data and information may accelerate customer responses and, through technologies such as precision agriculture, ameliorate the environmental impacts of food chain activities. While the digital revolution may transform the world of agriculture, the search for innovation guided by and towards sustainable development will continue. The sustainability of food innovations remains an idiosyncratic process with questions, problems and solutions specific to each society, each culture and each country. It also raises questions about the modes of governance that should be adopted to regulate the relationships between the actors responsible for the creation and processing of these data and who should capture the value generated by the knowledge resulting from data processing.

In Chapter 2, we will review the concepts, tools and methods currently used by organizations to develop responses to these issues. Through different perspectives and approaches, we will propose to illustrate the means and resources that organizations can use in their design, production practices and interactions with their stakeholders to transform business models and products in ways that increase their sustainability.