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Ángeles Pereira Sánchez

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Grupo de investigación Innovación, Cambio Estrutural e Desenvolvemento (ICEDE)

Departamento de Economía Aplicada
Universidade de Santiago de Compostela
Avda. do Burgo s/n
15782 Santiago de Compostela – A Coruña
Telf. +34 881 811 567
www.usc.es/icede

Characteristics of the dominant agri-food system: innovation patterns, environmental consequences and alternative paradigms

Ángeles Pereira Sánchez
Postdoctoral Researcher
Universidade de Santiago de Compostela (USC)
Telf. +34 881811701 angeles.pereira@usc.es

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Abstract

The objective of this paper is to undertake a literature review about the evolution and shape of the dominant agri-food system. The focus is on the evolution of innovation patterns and the main environmental consequences of the configuration of the modern agri-food system. The agri-food sector experienced huge changes along the twentieth century. Production of food was progressively subjected to industrial parameters and consumption patterns evolved towards new dietary habits and convenience food. Several economic, political and social factors explain this evolution but to a high extent, the development of scientific and technological knowledge is the main factor behind the changing profile of the agri-food system. The incumbent food production and consumption regime has great negative impacts in the environment. Partly as a response to these impacts, there have emerged recently alternative paradigms of food production and consumption.

Key words

Food system, innovation, environmental impacts, sustainability

JEL codes: O13, Q56

1. Introduction

The objective of this paper is to undertake a literature review about the evolution and shape of the dominant agri-food system. The focus is on the evolution of innovation patterns and the main environmental consequences of the configuration of the modern agri-food system.

Innovation is acknowledged as the engine of economic growth. However, until very recently, the impact of innovation in the environment has not been addressed by economic studies. The interest on studying technologies was and is yet in their contribution to growth and trade but hardly any attention is paid to their environmental and social consequences.

The agri-food sector experienced huge changes along the twentieth century. Production of food was progressively subjected to industrial parameters and consumption patterns evolved towards new dietary habits and convenience food. Several economic, political and social factors explain this evolution but to a high extent, the development of scientific and technological knowledge is the main factor behind the changing profile of the agri-food system.

The paper includes in the next section a broad description of the dominant agri-food system regarding the influence of innovation trajectories, public policy and the globalization of capital. In section 3 we look at the main environmental problems that are linked to the dominant industrialized and globalized agri-food system, by reviewing some relevant literature based on LCA and other methodologies. Finally, we review in section 4 some literature about alternative agri-food systems that are defined in opposition to the dominant agri-food system and defend themselves as sustainable agri-food systems. We finish this paper with a section of conclusions.

2. The profile of the dominant agri-food system

2.1 The configuration of the modern food system from the perspective of industrial dynamics

In this section we summarize the main changes occurred to the agri-food system mostly during the twentieth century that led to its industrialization and globalization. We adopt the perspective of theories of innovation, economic organization and competitive advantage.

Overall, it can be said that three key stages in the development of scientific and technological knowledge explain the main trajectories of the agri-food system: 1) the mechanization due to Industrial Revolution; 2) the spread use of chemical fertilizers and pesticides due to the Green Revolution; and 3) the new wave of genetic engineering linked to the development of biotechnologies.

The book *From Farming to Biotechnology* (Goodman, Sorj, & Wilkinson, 1987) suggests placing biological processes in the centre of a new perspective to address the specific dynamics of the modernization of agriculture. Thus, they describe the progressive industrialization of the agri-food sector as the result of partial appropriation and substitution processes facilitated by the advance of science and technology. In this way, new industrial sectors were brought forth, based on the identification of new capital accumulation areas upstream and downstream the farm.

'Appropriationism' refers to the action of industrial capitals to reduce the importance of nature in rural production. Along the history, two main lines of appropriationism may be identified:

- Agricultural mechanization, with its focus on the labour processes and the chemical properties of the soil;
- Chemical and genetic innovations, focused on the vital biological cycles of the 'natural' production process.

In essence, these advances in science and technology allowed for the progressive appropriation by industrial capital of activities that once comprised intrinsic elements of the next to farm or farm-level production process.

The discovery of some revolutionary techniques, such as crop hybridization, plant breeding or high-yield varieties, and their later internationalization through the so called Green Revolution, were the key to the progressive homogenization of the agricultural production process. Agro-industrial capitals, united with farm lobbies and supported by State policies, began then to direct the development path of the modern agri-food system.

In parallel, another process called 'substitutionism' was fostered by the chemical industry and the development of synthetics. 'Substitutionism' refers to the development of industrial substitutes for rural products, so the rural product can be reduced to a simple industrial input. This process basically meant placing an industrial activity between production and consumption.

Flour milling and sugar refining represented the key innovation techniques that allowed for the transition to industrial mass-production. In addition, the innovations occurred in traditional techniques of food separation and preservation –canning, refrigeration and dehydration-, together with the growth of manufacturing and rapid urbanization, the revolution in transport and communications, as well as the liberalization of trade, completed the factors that drove the change in consumption patterns.

Technological changes but also social and economic trends, such as the increasing participation of women in the labour force, the diffusion of domestic appliances for food preparation and conservation, new eating habits and greater affluence, are behind the great development of convenience and fast-food products. These trends favoured substitutionism: foodstuffs are reduced to their basic ingredients and these inputs are combined with additives to produce new products with industrial characteristics like convenience, dietary qualities, flavour, texture and colour.

In this way, mass-production and mass-consumption gave rise to new capital accumulation areas downstream the farm. The increasing power of food processors and more recently of food retailers in the agri-food value chain represents therefore a further step in the configuration of the modern agri-food system. According to Goodman et al (1987) in the absence of significant scale economies, the food industry put the emphasis on the extension of multi-plant operation achieved by mergers and takeovers. That had important effects on the organization of agricultural production, leading in many cases to vertical integration strategies.

In relation to more recent scientific and technological advances, the authors point out that the development of biotechnologies opens up new trajectories for the industrialization of agriculture through further 'appropriatonism' and 'substitutionism' processes. Biotechnologies find commercial application in biological nitrogen fixation; herbicide- and pest-resistant crops; more nutritional varieties of cereal grains; better adaptation of crops to the requirements of the food processing industry, etc. These applications tend to increase the dependence of farmers on technical solutions and boost further vertical integration. "The seed is the 'delivery system' of the new plant biotechnologies. Acquisition of proprietary rights to the improved plant varieties thus holds the key to control the agricultural production process and domination of the markets for agro-industrial inputs." (Goodman et al, 1987, p. 108).

In a similar vein, the capacity to quantify and predict inputs and outputs provides the basis for applications of microelectronics, computer technology and automation, like cost accounting, mixing feed, input purchasing and stock control, farm and market data analysis, and the use of data bases. "[…] the combined application of biotechnologies and automation offers an integrated industrial solution to agricultural production. For the first time, appropriationism has reached the point where it represents a truly industrial alternative to the rural, land-based organization of agricultural production." (Goodman et al, 1987, p. 123)

Moreover, substitutionism via industrial microbiology also seeks to reduce the importance of agriculture, creating food from non-food, even non-agricultural, feedstock and fermentation technologies. In this sense, other actors within the food system are affected too. Wilkinson (2002) highlights the idea that the traditional food industry must compete with new agrochemical companies that are able to focus on new contents of demand, such as nutriceuticals and functional food.

Nevertheless, despite the increasing industrialization of the agricultural process, the sector is still dependent on the specificities of nature and the environment. Industrial dynamics have not been able to achieve a whole appropriation of the food production process. Moreover, partly in opposition to that industrialized model and partly as an alternative for those who are not able to adapt to it (due to nature and culture constraints), alternative food production and consumption patterns can be identified nowadays (Morgan, Marsden, & Murdoch, 2006).

2.2 Sources of innovation in the modern food system

The classical taxonomy of sectoral patterns of innovation developed by Pavitt (1984) based on innovative firms, classifies the agriculture sector as a supplier dominated sector. These types of firms are usually small and have limited capacity to undertake internal R&D, so their contribution to develop their own product or process technologies is small. On the contrary, most innovations come from suppliers of equipment and materials, and eventually from large customers and government-financed research and extension services.

Broadening the focus, Goodman & Wilkinson (1993) studied the industrialization of the agri-food system in the US and UK. As they reported in previous studies (see Goodman et al, 1987), the industrial appropriation of single activities allowed the creation of the agro-industrial capital and the complex comprised of equipment, transformation, seed and phytosanitary product industries. According to the authors this fact turned out industrial sectors into autonomous sources of innovation, therefore able to influence public research orientations.

Goodman and Wilkinson (1993) state that three main factors are responsible for the dynamics of innovation in agricultural activity:

- R&D within the agriculture sector have been inhibited by the character of the production unit historically dominant, i.e. the undercapitalized familiar agriculture farm;
- Industrial innovation has been based on the fragmentation of the agriculture production process through the partial appropriation of rural activities by the industry;
- Traditionally, the State has been responsible for innovations in the biological area, because those innovations were not appropriable by the industry and at the same time they were out of reach for atomized and undercapitalized agriculture production units.

In a similar fashion, Possas, Salles-Filho, & Da Silveira (1996) adopt some concepts from evolutionist theories and suggest considering six groups of institutions as a taxonomy of innovation sources to understand the modern technological regime in agriculture. In their view, the way in which these institutions evolve and relate to each other is the main institutional driver that develops technological trajectories in agriculture:

- Private sources of business industrial organization. The main objective is to produce and sell intermediate products and machinery for agrarian markets. They are: pesticides industry; fertilizers industry; machinery and tools for agriculture; seeds industry. In the case of livestock farming some others may be included: veterinarian products; animal feed; genetic moulds; equipment to build farms.
- Institutional public sources: universities, research institutions and public research companies. Their basic purposes are: broadening scientific knowledge on animal and vegetal sciences and other related scientific fields; improvement in plants and animals, as well as the development of new cultures and breeds; establishing and prescribing the most efficient agrarian practices.

- Private sources related to agro-industry. It includes processing industries of agrarian products that influence the production of raw materials.
- Private sources, collectively organized and non-profit oriented. They are usually co-operatives and producers associations that aim to develop and transfer new varieties of seeds and agrarian practices.
- Private sources providing services, such as technical support, production planning and management, and services related to crops and cereals production, storage and animal breeding.
- Agrarian production units.

More recently, Vanloqueren & Baret (2009) adopt the evolutionist approach to support their hypothesis, which states that the agriculture research system has favored the development of biotechnology as a new paradigm for innovation in agriculture, while agro-ecological approaches based on the ecology paradigm have until very recently been denied.

The authors take a limited focus and consider three determinants of innovation: agriculture scientific policy, private sector research and public sector research. Each of these determinants influences innovation in agriculture according to different factors (see table 1).

Table 1: Determinants of innovation in agriculture research systems that induce an imbalance between genetic and agro-ecological engineering

Categories	**Sub-categories**	**Innovation determinants**
Agricultural science policies	Research orientations	Growth, competitiveness and biotechnology
	Relationships between public and private sectors	Public-private partnerships Public-private division of research labour
	Influence of lobbies	Imbalance in the power of lobbies
	Media	The media channel public opinion towards a single paradigm
Private sector	Research orientation	Focus on biotechnologies and importance of patents
Public sector	Cultural and cognitive routines (values and world-views of scientists)	Assumptions on current and future agricultural systems Assumptions on past agricultural systems Assumptions on nature and value of innovations

	Organization within research systems (rules of the game)	Views of complexity and framing of agricultural research Assessment of the performance of agricultural innovations Especialization vs. Interdisciplinarity Publish or perish Technology transfer missions: patents, spin-offs and extension

Source: Vanloqueren and Baret (2009, p. 975)

2.3 The role of public policy in the configuration of the modern agri-food system

The industrialization of agriculture was to a great extent favored by the commitment of public policy with the productivist approach after the 1940's (Munton, Marsden, & Whatmore, 1990). With their focus on productivity, profit maximization and free trade, public policies (especially support programs for agriculture, fiscal policies, rural workforce policies and research policies) favoured the big farmer and boosted the ongoing process of industrialization and corporate control (Goldschmidt, 1978, cit. in Daly & Cobb, 1997). Goodman et al (1987) attribute to the State a supporting role of agro-industrial capitals and farm lobbies, institutionalizing production surpluses and allowing the appropriationist strategies of agro-industrial capitals. Indeed, the authors distinguish several roles-stages in State intervention:

- Compensatory role: to offset fluctuations in food supply; funding of expeditions to collect new plant species; measures of price control;
- Establishing the conditions for a capitalist agriculture: agrarian reforms aimed at: a) the consolidation of the productive unit; b) the transformation of agriculture into a commercial project; c) the reorganization of agricultural production in accordance with advances in soil, plant- and livestock-breeding sciences.
- Favouring industrial appropriation by a) the provision of the financial and organizational capacity for agricultural modernization –credit and cooperativism; b) the development of research and extension systems to advance knowledge of the biological determinants of agricultural production not subject to industrial appropriation; c) the organization of production flows using fiscal, credit and marketing policies.
- Reorientation of public research priorities in order to avoid conflict with opportunities for private profit-making. The State is in charge of reconciling the conflicting effects of continued productivity

growth associated with industrial appropriation on productive capacity and output, rural incomes and rural social structures.

2.4 The globalization of the modern agri-food system

In economic terms, the dynamics of input suppliers, food processors and retailers depict a capital-intensive and highly specialized form of production, where the commoditization of agricultural inputs and national and global trade are the main features. Malassis (1979) describes the modernization of the agri-food system as a progressive process of capitalization, concentration and internationalization. He recognizes this process basing his analysis mainly on three factors:

- The structural change of the agri-food sector, characterized by the relative decline of the value adjusted by agriculture;
- The industrialization of the agri-food value chain, which meant the diffusion of industrial processes along the chain. Those processes are characterized by technical dominance, mass production, functional division and coordination of activities, as well as technological and organizational innovation. In addition, they involve high rates of capital and energetic consumption per asset. Mass consumption is based on mass distribution, which is founded on diversification, self-service and electronic management of stocks.
- The food product comprises increasing amounts of secondary ingredients (adjusted value and industrial inputs consumption) and tertiary element (convenience products: easy to preserve and cook).

Hendrickson & Heffernan (2002) consider that technological developments like genetic engineering, nanotechnology and information and satellite technologies provide multinational corporations with a greater control of the whole agri-food system.

Morgan et al (2006) draw attention to the power of the different actors within the agri-food system. In their book *Worlds of Food*, the authors highlight the strong position of global food supermarkets, which due to their direct contact with consumers and through strategies aimed at the establishment of health and safety standards, systems of preservation and supply chain tracking, achieve a huge control on food producers and manufacturers. In this sense, it has been suggested that not only farmers (or primary food producers) are squeezed by other actors within the modern food system but also the food industry is (Wilkinson, 2002).

Some authors see in this globalized agri-food system a new food regime, the 'corporate food regime' (McMichael, 2009), which is connected to the globalization of capital, in particular of financial capital. Delgado Cabeza (2010) identifies four general strategies that allow the expansion of the corporate food regime:

a) The financiarization of food: just within three five-year periods, global flows of foreign direct investments for agriculture, food and drink and distribution have increased fivefold. These flows are related to several activities that at the same time are exasperating the structural food crisis: new business opportunities linked to increase of agrarian prices and acquisition of land; intensification of the use of land for producing bio-fuels and crops for feeding animals; or the utilization of financial markets to speculate with food products prices.

b) The control of the agri-food game rules: under the principles of reduction of tariff barriers and the elimination of subsides and aid to agrarian produce, the Uruguay Round (1986-1994) supported by the World Trade Organization (WTO) began the liberalization of the international agri-food commerce. On the other hand, the biggest organizations are able to privatize the creation and implementation of specifications and norms about agri-food products and processes.

c) The utilization of new technologies: technological advances constitute an important barrier for small farmers and for sustainable practices of local food sourcing. On the contrary, big corporations make progress and create a greater distance with nature by using new inputs, technological automatized processes and privatisasing the genetic heritage of the planet.

The utilization of space and time: the big corporation is the central element that guarantees the performance of the industrialized and globalized agri-food value chain according to a specific pattern. "Within this structural framework each piece is relevant just as an interchangeable asset that may contribute to the growth of future perspectives about: the value expected by the shareholder, the market share, the profitability or even the spreading rate of the group. […] The crucial centre of the network –the big corporation, bases therefore, its growth not in wealth creation but in the attraction –appropriation, of that one already created. So the 'value' in this level consists of which it 'organizes the conquest: the transfer and subsequent domination of ever great social and natural parts of the world' (Ploeg, 2010, p. 147)" (Delgado Cabeza, 2010, p. 43). In this way global capital makes an optimal use of local conditions. Efficiency and profitability define the criteria to maintain farm activities and local food manufacturing and trade.

2.5 Consequences of the industrialized and globalized agri-food system on farmers

The industrialized and globalized agri-food system has led to a huge decline in the number of farmers in the entire World. The substitution of tractors for people that accompanied the modernization of agriculture took a part. However, the decline in farms population is also related to the pressures of the system. The dominant food system makes farmers a simple link in a long value chain, where their function is limited to provide raw materials. In many cases, the only way to adapt to this system is to grow under contract.

Within the modern food system, the farmer receives fewer each time. The value of food production is appropriated downstream, by processors and especially by retailers. As a consequence, less people can have a living from farming.

In addition, the industrialization of agriculture through appropriatonism led to the progressive lock-in of farmers into a system highly dependent on external knowledge (Goodman and Wilkinson, 1990; Munton et al, 1990; Morgan & Murdoch, 2000). Morgan & Murdoch (2000) study the process of industrialization and standardization of agriculture for the UK case, focusing on the distribution of knowledge. According to the authors, the emergence of industrialized agri-food networks led to a new redistribution of knowledge far away from the farm.

The productivist mode of agriculture after the 1940's was supported by a strategic economic rationality, the political and authority commitment, and the technological innovation aimed at increasing product and productivity. Within this framework, farmers were put under pressure. In order to maintain their competitiveness, they were obliged to put the prices down and increase their product. That meant the growth in the use of capital intensive technologies, mainly represented by the generalized adoption of chemical inputs. Thus, in contrast to farmers' local and tacit knowledge about land and its organic features, as well as traditional management skills, chemical products gave rise to a new relationship between farmers and agriculture. They became dependent on the standardised and codified knowledge provided by chemical sprays instructions (Morgan & Murdoch, 2000) and on information and advice provided by commercial staff and extension services.

In more recent years, biotechnologies threaten with tightening this relationship, since they make farmers even more dependent on knowledge and practices lead by industrial interests. "As with the Green Revolution, new crop varieties again will form the nucleus of 'technological packages', but genetically engineered seeds now will ensure that farmers are bound far more closely to proprietary agri-chemicals." (Goodman et al, 1987, p. 110)

The authors foresee the growth of part-time farming, with farmers acting as virtual or actual renters, as well as the greater recourse to custom services for many activities, due to the increasing capital cost and technical sophistication of farm machinery together with the wider application of microelectronics. In this sense, they think that the application of modern biotechnologies marks the decisive break with traditional farm knowledge. "The farmer will give way to the 'bio-manager' and observation will be replaced by 'software'" (Goodman et al, 1987, p. 184)

3. Environmental impacts of the dominant agri-food system

Nowadays, Western consumers can enjoy food from all over the World at any season. It might be said that, based on technological progress and the liberalization of international trade, consumers in developed countries have achieved, at the moment, certain independence from the Nature's boundaries.

Nevertheless, this does not mean that consumers in developed countries today are best fed than ever or that they have overcome the food crisis. On the contrary, general statistics show that many problems arise derived from food consumption patterns, mostly related to health and insecurity aspects. Moreover, although a great deal of food is wasted every day, more consumers in developing countries are dying from hunger. And on top of that, environmental problems derived form these patterns of food production and consumption are becoming more and more evident.

Morgan and Murdoch (2000) point out that the conventional model of agriculture and food consumption is in crisis. That crisis arises from three main sources: 1) the increasing cost of supporting agriculture; 2) the deep concerns about the food quality; and 3) the visibility of environmental externalities. In this section we will focus on the main environmental impacts of the industrialized and globalized agri-food system as reported in the literature.

3.1 Sources of unsustainability

The industrialized and globalized agri-food system requires the intensive use of resources and energy along each stage of the value chain (input suppliers, grown produce, processing, distribution, transport and consumption).

Agroecologists and environmentalists tend to highlight the problems that arise due to the intensive use of natural resources. In some way, the modernization of the agri-food system meant the shift from agriculture linked and respectful with nature to another one that damages it and therefore questions its sustainability. "The techniques, innovations, practices, and policies that have allowed increases in productivity have also undermined the basis for that productivity." (Gliessman, 2007, p. 3). The key question is that agriculture needs the nature but at the same time it modifies the nature, with the subsequent consequences in agriculture. Thus, it is essential for agriculture to maintain nature in the best possible conditions in order to guarantee its own sustainability. "Agricultural resources such as soil, water and genetic diversity are overdrawn and degraded, global ecological processes on which agriculture ultimately depends are altered, human health suffers, and the social conditions conducive to resource conservation are weakened and dismantled." (Gliessman, 2007, p. 8)

In the stage of agriculture, which is the base of the agri-food system, Gliessman identifies the main environmental damages caused by intensive modes of production:

- Soil degradation, in the form of salting, water logging, compaction, contamination by pesticides, decline in the quality of soil structure, loss of fertility, and erosion by wind and water;
- Overuse of water and damage to hydrological systems. More than two thirds of global water use is devoted to agriculture. The overuse of water is due in part to the specialization in water-intensive crops and to the necessities of livestock factories;

- Pollution of the environment. Farming practices result in contamination or degradation of the environment and the ecosystem. Animal management and the spread use of pesticides and fertilizers are the main origin of environmental damages in land, water and air.
- Loss of genetic diversity, which has occurred mainly because of conventional agriculture's emphasis on short term productivity gains. It is also accompanied by the genetic homogenization of crops and livestock, which allows standardization of management practices and therefore the maximization of productive efficiency. These two processes make crops more vulnerable to attack by pest and pathogens that acquire resistance to pesticides and defensive compounds of the plants as well as to changes in climate; livestock are also more vulnerable to disease and dependent of industrial production, requiring climate-controlled environments, antibiotics and high-protein feed.

Furthermore, the dependence on external inputs (material substances such as irrigation water, fertilizer, pesticides, and processed feed and antibiotics; the energy used to manufacture these substance, to run farm machinery and irrigation pumps, and to climate-control animal factories; and technology in the form of hybrid and transgenic seeds, new farm machinery, and new agrochemicals), often non renewable and finite resources, leaves farmers, regions and whole countries vulnerable to supply shortages, market fluctuations, and price increases. In addition, farmers' profits and the locus of control of agricultural production are affected.

Apart from environmental problems, Gliessman adds some social consequences of intensive agriculture. Firstly, the loss of local control over agricultural production, which in developed countries is represented by the huge decline in the number of farms and farmers and the farmers' loss of capacity for decision making as well as their squeeze between production costs and marketing costs. Secondly, the global inequality, with hunger as a systemic and persistent problem all over the world. The global food system makes developing countries dependent on exportations to developed countries, and on external inputs and technology for developed countries.

Strong dependency on fossil fuels

Earlier studies on the sustainability of the intensive model of food production were carried out in the US after the Green Revolution. By that time, the main concern of researchers was on the dependency of fossil fuel and the problems of energy shortages and cost increases. For instance, Pimentel et al. (1973) expressed their concerns about the high dependence of the US food system on energy use. "Fossil fuel inputs have, in fact, become so integral and indispensable to modern agriculture that the anticipated energy crisis will have a significant impact upon food production in all parts of the world which have adopted or are adopting the Western system" (Pimentel et al, 1973, p. 443).

Based on estimations according to real data in that moment, the authors demonstrated the lack of sustainability of spreading the US model of food production to the rest of the world. "Using US agricultural technology to feed a world population of 4 billion on an average US diet for 1 year would require the energy equivalent of 488 billion gallons of fuel. […] If petroleum were the only source of energy and if we used all petroleum reserves solely to feed the world population, the 415-billion-barrel reserve would last a mere 29 years. The estimate would be 107 years if all potential reserves of petroleum were used for food production." (Pimentel et al, 1973, p. 448)

A similar study by Steinhart & Steinhart (1974) also criticized the food production model of the US and technological optimism. "To feed the entire world with a US type food system, almost 80 percent of the world's annual energy expenditure would be required just for the food system." (Steinhart and Steinhart, 1974, p. 312). The authors were pessimistic about the future of energy-intensive food production and foresaw less energy-intensive food production or famine for many areas of the world.

Although environmental impacts due to the grown stage are usually the main focus of attention, when assessing the sustainability of the modern agri-food system, the performance of other stages must also be analysed. The strong dependency of the food system on non renewable fossil energies is evident: from intensive use of industrial inputs to the strong dependency of technological applications to process, preserve and prepare food, going through the continuous use of transportation. Before identifying the main hot spots in the agri-food system, we summarise the main approaches to measure sustainability problems.

3.2 Approaches and methods to measure sustainability of agri-food systems

There are various interpretations of what sustainability means in relation to the agri-food system. Accordingly, several methods have been suggested and undertaken to measure it, from energy accounting, economic valuation of non-marketed goods and services, ecological and carbon footprints, to the use of indicators for sustainability (Pretty, Ball, Lang, & Morison, 2005).

There are also two general approaches in order to identify the hot spots in the food value chain: bottom-up and top-down. The bottom-up approach begins with an individual product and conducts a Life Cycle Assessment (LCA) of it. The results for this particular product are then assumed to be representative for a wider range of products and so are extrapolated to a much larger group of products.

The top-down approach begins with economic input-output tables, which describe production activities in terms of the purchases of each industrial sector from all other sectors. When they contain data about the emissions and resource use of each sector, this information may be used to calculate the environmental impacts of products covering the full production chains. In this case the information is quite aggregated.

3.3 Empirical evidence of main hot spots

Depending on the objectives and background of researchers, literature offers different insights in relation to the hot spots of the agri-food system.

3.3.1 GHG emissions

Many recent studies take a life-cycle approach and focus on GHG emissions in order to identify the main hot spots along the food value chain. To our knowledge, there is not an analysis of the global food chain as a whole. A report from the IPCC (2007) identifies the main sources of GHG emissions due to agriculture. Globally, it accounts for 10-12% of anthropogenic greenhouse gas emissions. In particular agriculture contributes with 47 and 58% of total NH_4 and N_2O emissions. These both gas emissions increased a 17% from 1990 to 2005, mainly due to biomass burning, enteric fermentation and soil emissions. The projections are that these two gas emissions will increase until 2020-2030 by 50-60%.

Taking a top-down approach, the EIPRO project IPTS/ESTO (2005), conducts an analysis based on input-output tables for the EU-25. Comparing its estimations with LCA results in the literature, the study finds out that food and beverages account for 20-30% of the total impacts per category (abiotic depletion, global warming, photochemical oxidation, acidification, human toxicity potential and ecotoxicity) and almost 60% of eutrophication impacts.

Garnett (2008; 2010), who focuses on food consumption in the UK, offers a clear overview of sources of greenhouse gas emissions (GHG) according to each stage in the food chain (see figure 1).

Figure 1. Food chain impacts and the distribution of different gases

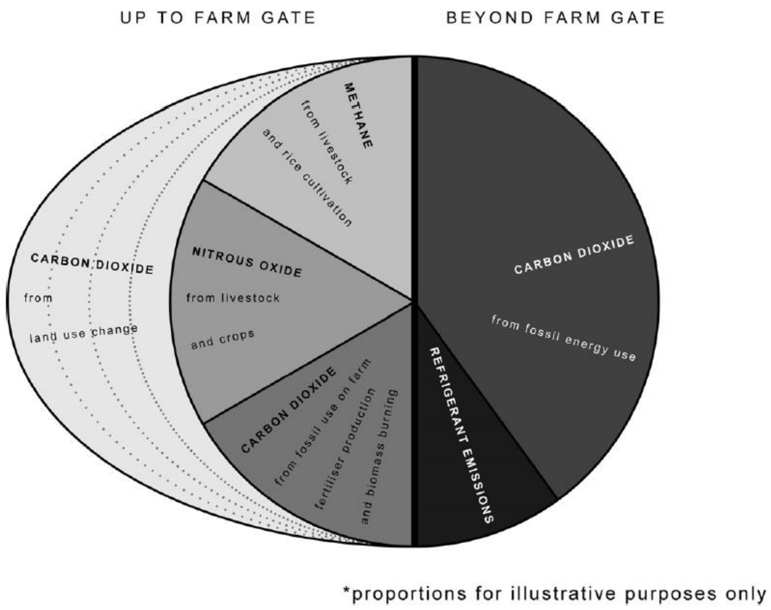


Fig. 1. Food chain impacts and the distribution of the different gases.

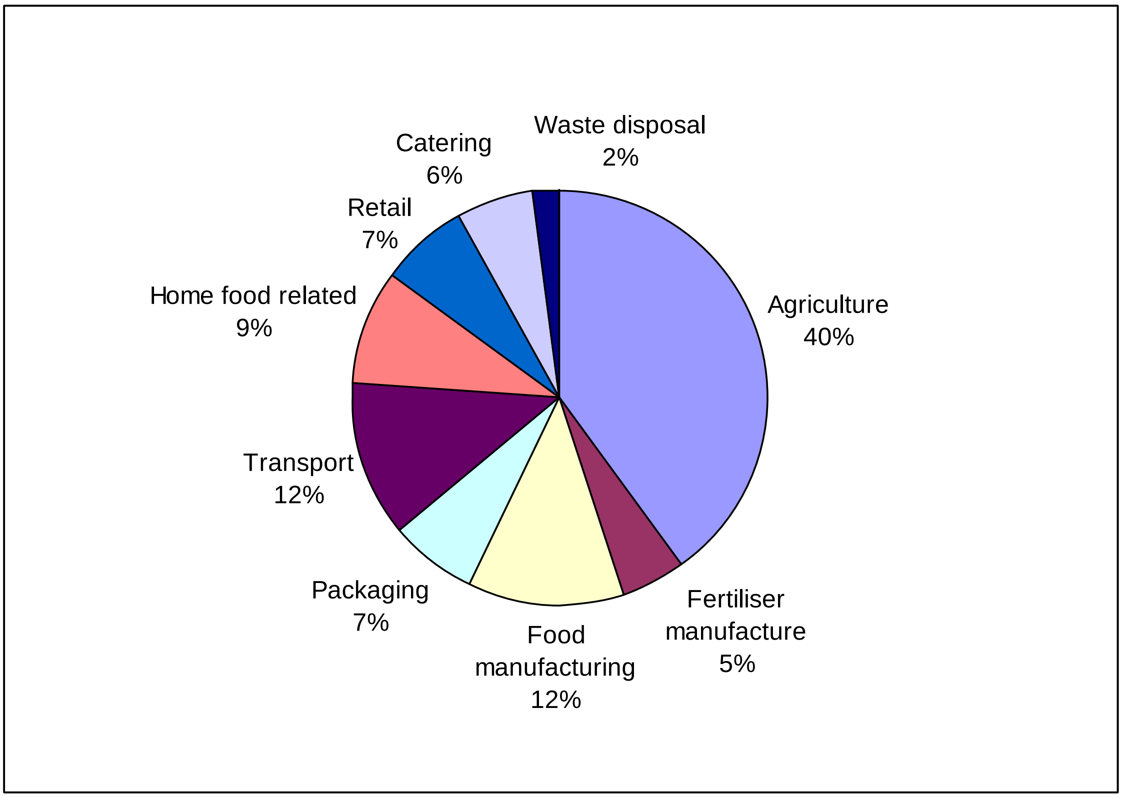
Source: Garnett (2008)

The main sources of GHG emissions are linked to different processes upstream and downstream the farm:

- To farm-gate: nitrous oxide (N_2O) from soil and livestock processes (manures, ourin, and nitrogen fertilizers) and methane (CH_4) from ruminants' digestion, rice crops and anaerobic soils. Carbon dioxide (CO_2) emissions from burning fossil fuels for machinery, from the production of synthetic fertilizers and from burning biomass. CO_2 derived from the shift in land use induced by agriculture may add important impacts in this stage.
- Post farm-gate: CO_2 emissions from fossil fuels use are dominant, and those from refrigerant emissions are also important.

Based on extensive literature review and workshop seminars with stakeholders from the food industry, government, universities, non-governmental organisations and consultancies, as well as on sharing knowledge with many people with varied backgrounds belonging to the Food Climate Research Network (FCRN), Garnett (2008) depicts the breakdown of food chain GHG emissions in the UK, excluding land use change, in the next figure.

Figure 2: Food chain GHG emissions in the UK



Source: Garnett (2008)

Several measures are being implemented to address the negative environmental impacts of the agri-food sector. Diverse technological and managerial approaches are suggested to improve the performance of the modern food system. Nevertheless, Garnett (2010) points out the necessity to evaluate in advance the possible consequences, since the existence of rebound effects shows that any measure have intended and unintended effects. "The nexus of technologies that characterizes and has created our modern food system has had an important role in shaping our food habits and expectations. Hence technological approaches to achieving emission reduction within transport, manufacturing and refrigeration need to be assessed in terms of the extent to which they foster a shift towards, or away from, further reliance on energy using technologies" (Garnett, 2010, p. 7).

Weber & Matthews (2008) adopt the input-output life cycle assessment (I-O LCA) to estimate the total life cycle GHG emissions associated with the production, transportation and distribution of food consumed by the average American household. Although food is transported long distances in general (1640 km delivery and 6760 km life-cycle supply chain on average) GHG emissions associated with food are dominated by the production phase, which contributes 83% of the average US household's 8.1 t CO_2e/yr footprint for food consumption. According to their study, transportation as a whole represents 11% of life cycle GHG emissions and final delivery from producer to retail contributes only 4%.

With a more restricted focus, Coley, Howard, & Winter (2009) use carbon emissions accounting to compare the impact of food miles in two contrasting distribution systems in the UK: a large scale vegetable box system and a supply system where the customer travels to a local farm shop. The analysis is based on fuel and energy use data collected from the UK's largest supplier of organic produce and focuses on the stages of storage, distribution and the retail chain. For the large scale system, the bulk of the emissions arise not from chilling or mass transportation using heavy goods vehicles but from the final delivery phase using large goods vehicles. Although the box scheme results in many more food kilometres than purchasing from a local farm shop, the authors highlight the fact that these are share between a large numbers of boxes. Therefore, they conclude that what matters is the carbon emissions per unit of produce over the transport chain and not the food miles concept per se.

3.3.2 Other impacts

Although GHG emissions constitute a useful and good indicator of sources of unsustainability along the food supply chain, it offers an incomplete appraisal of environmental impacts. Other authors have carried out studies based on different indicators to identify the hot spots or to compare several aspects of food production and consumption:

Heller & Keoleian (2003) adopt a life cycle approach and develop several indicators to examine the trends and identify which factors are questioning the sustainability of the US food system. By examining a comprehensive set of economic, social and environmental indicators covering all the stages of the US food system (origin of resource, agricultural growing and production, food processing, packaging and distribution, preparation and consumption, end of life), they find out that various trends threaten the productivity growth, like the reliance on limited genetic resources that are managed by corporate interests rather than public ones; the fact that the number of farmers is declining and their age is increasing; the fact that farm income is insufficient to sustain farmers and their families; and that small producers, who are not able to acquire modern machinery, depend on hiring low-wage illegal labour. In relation to the environmental dimension, soil erosion and fresh water availability, together with the high dependency on non-renewable energy, which also increases the food system vulnerability to supply side price increases in fossil fuels, are the most relevant problems. Finally, their assessment also points out to the health and social costs of diet related diseases, and the great deal of food that is wasted at the consumer level.

Kytzia, Faist, & Baccini (2004) adopt an economically-extended material flow analysis (EE-MFA) to understand resource use and distribution of total money input along the food production chain. The model is based on input-output tables and material flow analysis of food products and major food products used to produce food (fodder, pesticides, fertilizers and packaging materials). As environmental indicators they take land use and primary energy demand considering that they are important in terms of environmental impacts such as greenhouse gas emissions and loss of biodiversity. The final results show that almost the entire land (99%) of the food system is used in agriculture; about 80% of total energy consumption is evenly distributed between agriculture (25%), households (27%) and industrial processes (processing 12% and retailing 15%); the rest is used to produce pesticides, fertilisers and packaging (13%) and for the various transports (8%).

Pretty et al. (2005) calculate the full cost of the UK weekly food basket by analysing the environmental costs to the farm gate for each major food commodity, and the additional environmental costs of transporting foods to retail outlets, and then to consumers' homes, and the cost of disposal of wastes. In particular, the analysis undertaken assesses 19 categories of environmental costs for each of these commodities: cereals, potatoes, oil seed rape, sugar beet, fruit, vegetables, beef/veal, pork, poultry, mutton/lamb, milk and eggs. The categories of environmental costs referred to: pesticides, nitrates, phosphate and soil erosion, Cryptosporidium pathogen, eutrophication, monitoring, methane emissions, ammonia, nitrous oxide, carbon emitted from fossil fuel use, indirect energy cost from the manufacture of pesticides and fertilizers, offsite soil erosion, organic matter carbon losses, biodiversity and wildlife, losses of landscape features, bee colony losses, acute pesticide adverse effects, costs to consumers from outbreaks, and BSE and new variant CJD costs.

The authors conclude that the weekly food basket rises in cost from the £24.79 paid by consumers by £2.91 per person wk-1 (11.8%), with farm externalities (81.2 p) domestic road transport (75.7 p), government subsidies (93 p) and shopping transport (41.1 p) contributing the most. Yet, they recognise that the full cost could be underestimated since some environmental side effects in the food chain were not assessed (energy consumed by processors, manufacturers and wholesalers for light, heat, refrigeration and transport, disposal of food packaging, methane emissions from landfill and sewage waste, and the energy required for domestic cooking).

Foster et al. (2006) summarise the evidence found in the literature for the environmental impacts of single food products in a typical "UK trolley". In their sample they try to compare organic vs conventional grown produce, fresh vs processed food, locally-sourced vs globally-sourced food, and take into account different sources of nutrition. Their general conclusions show how difficult is make general statements:

- For many foods, the environmental impacts of organic agriculture are lower than for the equivalent conventionally-grown food. However, organic produce also poses some important environmental problems in terms of nutrient release to water, climate-change burdens or land-use requirements.
- Evidence for a lower environmental impact of local preference in food supply and consumption when all food types are taken into consideration is weak. Due to the wide variation existent in the agricultural impacts of food grown in different parts of the world global sourcing could be a better environmental option for particular foods.
- Overall, the higher the energy consumption for refrigeration, the higher the environmental impact of food products. However, this measure does not have into account the wastage levels arising in each of the cases.
- The environmental impacts of transport are significant. Taking a single food product, it is suggested that the impacts of car-based shopping are greater than those of transport within the distribution system itself.
- The environmental impact of packaging is high for some foods; it is usually related to the relation between the weight of the product and the weight of packaging. However, conclusions from LCA studies are divergent, due to context sensitivity and the functionality delivered by different forms of packaging.

Sim, Barry, Clift, & Cowell (2007) carry out a LCA analyses of three fresh products (royal gala apples, runner beans and watercress) in order to compare the environmental impacts due to in which countries the food is cultivated. Their analysis shows that transport and electricity consumed for storage and packaging operations are both important sources of impact. As a conclusion, the authors recommend that when in season it is preferable for UK consumers to buy British produce rather than produce imported from overseas. However, provided that cultivation overseas is necessary to guarantee supply all year round, it is preferable that processing activities also occur overseas if environmental benefits can be derived from local factor, such as more favourable electricity generation mix.

Roy et al. (2009) undertake a review of LCA analyses of several food products and processes (industrial food products, dairy and meat production, other agricultural products, land and water, packaging systems, food waste management systems) and find out that agricultural production is the main hotspot in the life cycle of food.

3.4 Environmental impacts of the Spanish agri-food system

The environmental dimension of the Spanish agri-food system has not been widely addressed. Only a few studies cover the whole Spanish agri-food system in their analysis. One of this is the work by González de Molina & Infante Amate (2010). This study estimates the energy consumption from six activities along the Spanish agri-food chain: consumption from food and agrarian produce, transportation at national and international level, processing, packaging, energy cost from food shops and expenses from preservation and cooking in households. The study is based on primary energy demand required for direct consumption in each stage along the value chain.

The most important insights are summarized below:

- The average per capita Spanish diet, which represents more than 3,000 kcl (in terms of dietary energy supply), requires 109 M tm of animal and vegetal biomass or 6,65 kg per capita per day.
- Globally, agriculture stands for the higher energy consumer (34.1%). Within this stage, the more energy-demanding processes are: fuels for tractors and irrigation pumps (11.5%), fodder (9.3%) for feeding intensive livestock; fertilizers, especially nitrogen (8.3%) to artificially restock soil nutrients;
- Transportation is responsible for a 17.4% of the total energy demand of the Spanish agri-food system, with transport by road (interregional and international importation) and home delivery being the most important categories;
- As a whole, processing and packaging require around a 20.0% of total primary energy. Plastics, which require a 9.6% of total energy demand, are the most important materials used to packaging food. This reflects the necessity of modern food to be preserved to avoid damages during transportation and storage and to keep its properties before being consumed. Processing (9.8%) is another characteristic of the modern food system, where industrial activities transform primary grown produce, together with other additives, into food products with a wide range of characteristics in terms of tastes, flavours, colours, convenience and so on;
- Commercialization of food represented by catering and retailing, requires another 9.6% of the total energy in the Spanish agri-food system. It is worth noting the increasing importance of the cold chain in this model of food production and consumption;
- Finally, household consumption is another important stage in terms of energy demand (18,4%). In particular, electronic appliances to preserve and to cook food require a 11.6% of energy.
- Globally the Spanish agri-food system requires more than 1,400 M GJ to satisfy the endosomatic metabolism of Spanish people, whereas dietary energy supply is about 235 M.

According to careful estimations the authors consider that each food energy unit needs another 6 to its production, distribution, transportation and cooking.

Another interesting study, in this case based on the Life Cycle Assessment (LCA) methodology, is the one carried out by Muñoz, Milà i Canals, & Fernández-Alba (2010). The objective was to assess the contribution of the average Spanish diet including the whole life cycle of food to global warming potential, acidification potential, eutrophication potential and primary energy use. The work is based on an extensive literature review on life cycle assessment data for Spanish food products and other databases and literature sources. The main results are as follows:

- The net global warming potential related to feeding an average Spanish citizen during a year is 2.1 tons CO_2-eq. Food production, especially meat and dairy products contribute the most (54%); human excretion and wastewater treatment plant (WWTP) is the second most important life cycle stage (17%), due to carbon releases in respiration, wastewater treatment, sludge disposal, and auxiliary materials (toilet paper, soap and tap water); home processes are also important;
- The eutrophication potential is dominated by the food production stage, with meat, dairy and beverages (wine and beer) responsible for a 60% of the impact in this stage; human excretion and WWTP is the second most important stage (17%) due to the release of nitrogen and phosphorous compounds in the treated sewage;
- The overall primary energy use per capita and year is 20 GJ. Food production and home processes (storage and cooking) are the most important contributors.
- Acidification potential is mainly related to food production (especially meat and dairy) and to a lesser extent to home storage and cooking.

More specific studies, mostly using a bottom-up approach, offer partial evaluations of environmental hot spots of specific food products. We summarize in the following table the main findings:

Table 2: Summary of studies about evaluation of environmental hot spots of specific food products.

Reference	Study focus	Methodology	Main results
(Vázquez-Rowe, Villanueva-Rey, Moreira, & Feijoo, 2012)	Viticulture, vinification and bottling and packaging in a winery of the Ribeiro appellation (Galicia) in order to identify the largest environmental impacts for four different years of production (2007-2010)	Life cycle assessment based on data collected through questionnaires.	The main hot spots identified were compost and pesticide production, fertilizer emissions, and diesel consumption and production process in the agricultural phase; bottle production and electricity consumption in the subsequent stages of wine production. In terms of aquatic eco-toxicity, the viticulture system was responsible for a 98% of the total impact, mainly related to the use of three specific pesticides: copper, folpet and terbuthylazine.
(Vázquez-Rowe, Villanueva-Rey, Iribarren, Teresa Moreira, & Feijoo, 2012)	To determine the level of operational efficiency of 40 vine-growing exploitations belonging to the Rías Baixas appellation (Galicia). Focus on cultivation and harvesting processes.	Combined implementation of Life Cycle Assessment and Data Envelopment Analysis (LCA + DEA methodology)	Differences depending on farms production size: wine-growers with low production exploitations presented an average efficiency of 79%, lower than that of intermediate production vineyards (83%) and high production sites (86%) mainly due to diesel consumption, phtalamide pesticides use and copper-pesticides application. A total of 5 inputs presented an individual efficiency score below the efficiency score of the average exploitation: diesel, organic fertilizer, Cu-pesticide carbamates and N-fertilizer.

(Moreira, Vázquez-Rowe, Villanueva, & Feijoo, 2011)	The viticulture stage of Rías Baixas production with the objective of identifying the hot spots of grape harvesting for three production years (2008-2010)	Life Cycle Assessment based on data collected through questionnaires	Environmental impacts per functional unit (1.1 kg of harvested grape) varied considerably on an annual basis; The main hotspots are linked to diesel use and its production; fertilization application and their emissions; and the production of pesticides. Field operations also presented important contributions to land competition; and steel trellis in the vineyard accounted for relevant contributions for global warming potential and land competition.
(Milà i Canals et al., 2010)	Case study of UK consumption of broccoli grown in the UK and Spain.	Water footprint and Life Cycle Impact Assessment.	Total water consumption does not vary greatly between UK and Spanish broccoli production; Impact assessment indicators based the water use per resource ratio show that water use in Spain is much more critical, with significantly higher impact for Spanish cultivation; The largest component of water use in Spain is linked to irrigation, although other important uses in the life cycle of vegetables are cooking and sanitation, land use effects on the water cycle and electricity consumption.
(Gazulla, Raugei, & Fullana-i-Palmer,	To identify the most critical life cycle stages of an aged Spanish wine from La Rioja, taking into account grapes	Life Cycle Analysis	Almost one half of the greenhouse gas emissions are derived from the viticulture stage mainly due to release of dinitrogen

2010)	cultivation, wine making and bottling, distribution and sales, and disposal of empty bottles.		monoxide (N_2O); ammonia and nitrogen oxide emissions caused by fertilizer use contribute the most to the acidification potential; fertilizer use is also responsible for eutrophication category; and cumulative water demand reach its most in the viticulture stage, specifically in the phytosanitary treatment step; Glass production for bottle manufacture is the second source of global warming potential, the first one of acidification potential and photochemical ozone creation potential, as well as the main user of gross energy; The distribution and disposal stages cumulative account for a relatively small portion of environmental impact indicators (up to 15%). However, the alternative scenario for international distribution to the UK almost doubled impact indicators, due to larger transport distance but also to the lower percentage of end-of-life glass recycling in the UK in comparison to Spain.
(Hospido et al., 2009)	To analyse the impacts (global warming potential, acidification, energy use, land use and water use) associated with producing (from plant propagation to harvesting and post-harvest cooling) and delivering 1 kg	Life Cycle Assessment	Higher contributions for indoor lettuce production over winter in the UK (due to requirement of energy for heating) when compared to lettuce imported from Spain, in terms of global warming potential and primary energy use;

	of lettuce to a UK Regional Distribution Centre.		When compared with summer outdoor production in the UK, lettuce imported from Spain only displays a light increase in primary energy use (it is almost related to refrigerated transport). The most significant differences between indoor UK production and imported field lettuce produced in winter lie in land use and water use.
(Meneses, Pasqualino, & Castells, 2012)	Assessment of global warming potential and acidification of the most common packaging options for milk on the Spanish market; the production of the various packaging materials and sizes and their final disposal (land filling, incineration and recycling); and of the milk cycle (production, transport, packaging production and packaging disposal).	Life Cycle Assessment	Aseptic cartons present the lowest impacts for all the indicators and disposal scenarios while the impact of both types of plastic packaging (HDPE and PET) is similar; Milk production has the greatest environmental impacts in terms of global warming and acidification potential; however, the formulation of animal feed at farms and emissions from boilers at dairies are also decisive; the study only considers local distribution (100 km) so if imported milk was taken into account it would likely increase its impacts; Recycling beverage packaging materials has a lower environmental impact than disposal in landfills or incineration plants, for all materials and sizes compared.

(Vázquez-Rowe, Moreira, & Feijoo, 2012)	To assess and compare the environmental impacts related to the capture, processing and exportation of packed frozen Octopus from the Mauritanian EEZ to Spain, Italy and Japan.	Life Cycle Assessment	The environmental impacts are linked mainly to onboard activities of the cephalopod trawling vessels. This industrialized subsystem comprises extraction, processing (weighing, gutting and freezing) and preliminary packaging of the product; the main cause of environmental burdens is the strong dominance of energy use in trawling fisheries; Major impacts are related to fuel use and production, as well as to R22 emissions due to freezing operations and storage; Post-harvesting operations are deemed as insignificant, regardless of the exporting route. This is due to the fact that marine freight is the selected transport method.

Source: own elaboration

4. Alternative paradigms of food production and consumption

The weaknesses of the dominant agri-food system open space for alternatives (Hendrickson and Heffernan, 2002). Alternative practices and relations of food production and consumption are often identified as those related to agroecological, animal welfare or social values, such as organic, free-range and fair trade (Scrinis, 2007). These labels represent typically commodified alternative end-products which are identified by carrying certifying labels and often entail a price premium. In addition, these products are often based on different supply chains or networks that connect producers and consumers. Scrinis (2007) identifies shorter and less exploitative supply chains, more localised food distribution channels, alternative retailing that bypasses supermarkets chains and more direct exchanges and relationships between producers and consumers. This also matches with alternative patterns of consumption, related to a different aesthetic and appreciation of food, as well as to wider concerns about the environmental and economic conditions of production. Scrinis (2007) refers to practices such as purchasing alternative agri-food end-products, purchasing food through alternative distribution and exchange networks and decommoditization of food consumption practices (e.g. growing one's food locally, removing some of the commercial processing and value adding stages of food preparation and the refusal to eat certain foods for environmental, animal welfare, health or socio-economic reasons).

In more abstract terms, the alternative paradigm of food production and consumption is defined in relation to a "more holistic logic of identity, embracing different dimensions of food aesthetics, ethics, sociality, purity, naturalness, and potential social countermovement" (Morgan et al, 2006, p. 71).

Morgan et al (2006) distinguish alternative food supply networks from the conventional food system in terms of knowledge, authority, power, regulation, space and spatial competitiveness. According to their view, the concept of 'value-capture' defines alternative networks, and has at least three potential dimensions (Morgan et al, 2006, p. 74):

- Producers and their networks attempt to capture more of the economic value of their products;
- New mechanisms for distributing value among producers and processors are required;
- Alternative food chains can stimulate multifunctional forms of value-capture, by forging synergies between agricultural practices and other activities, such as tourism.

The expression of sustainable alternative food networks refers, definitely, to new social networks and entrepreneurial initiatives focused on "investing in the local environment, creating and strengthening local institutions, and employing people and their resources" (Morgan et al, 2006, p. 74).

Gliessman (2007) considers that two requirements are necessary to create a more sustainable food system:

- A change in diets, based on the reduction of meat and other animal products, as well as all food products that are largely transported, processed and packaged;
- A grown model based on independent and relatively small-scale farmers committed with their communities, able to make a decent living and independent of the agribusiness oligopoly.

The author identifies some key features of an alternative food system (Gliessman, 2007, p. 332):

- Food production and consumption has a bioregional basis;
- The food supply chain has a minimum number of links;
- Farmers, consumers, retailers, distributors and other actors exist in the context of an interdependent community and have the opportunity for establishing real relationships;
- Opportunities exist for the exchange of knowledge and information among all those who participate in the food system.

Other authors have made similar proposals. Horlings & Marsden (2011) propose a new concept to understand the alternative agri-food system. They define the eco-economy as “complex networks or webs of viable businesses and economic activities that utilise the varied and differentiated forms of ecological resources in more sustainable and ecologically efficient ways. Importantly, these do not result in a net depletion of resources, but instead provide cumulative net benefits that add value to rural and regional spaces in both ecological and economic ways” (Horlings & Marsden, 2011, p. 444).

Adopting the perspective of ecological modernization, the authors show that the eco-economic paradigm in the agri-food sector comprises several elements that allow it to be distinguished from the conventional agri-food system across different dimensions (see table 2)

Table 3. Weak and strong ecological modernization in agriculture and agri-food networks

Dimensions	Weak ecological modernization	Strong ecological modernization
Economical	Corporatization Productivity (yield) oriented Cost-price squeeze on agriculture	Agri-food networks Integral approach Food security Value-adding at farm level

Technological	Economically driven technology development Technological environmental solutions Closed loops of energy, waste and minerals	Technological generation as a demand-driven process and spatially sensitive
Ecological	Ecological and genetic engineering (industrial ecology)	Based on agro-ecological principles, flexible and adaptive to specific ecologies and places
Social-cultural	Dependency, scientification, rational man-nature relation, loss of farmers freedom / agricultural employment	Sovereignty Autonomy Synergy between man-nature Demand-driven research (mode 2 science) Labor-intensive
Spatial	Globalized Export-oriented Use of external resources	Locally embedded in the community Endogeneity Use of local resources
Political	Top-down steering One-direction communication by extension services Power concentrated at multinationals and large retailers Privatized research & development	Enabling policy Participatory approaches Influence of communities in agri-food networks Local and regional institutional actors

Source: Horlings and Marsden (2011, p. 446)

In view of systems innovation literature, alternatives such as the organic food system represent niches that challenge the dominance of the conventional food system (Smith, 2006). It is suggested that in order to influence the incumbent regime, niches must be flexible and compatible with it. Paradoxically, it also means a weakness for niches in terms of holding their radical features. If the aim is to foster a transition towards sustainability, it is argued that public policies must enable radical innovation represented by niches and pressure incumbent regimes to search for solutions to their problems.

Several studies have focused on the relations between alternative niches and the dominant food regime. Guthman (2004) for instance, focuses on the organic sector in California and conceptualises the appropriation of alternative by the mainstream as 'conventionalisation' of the alternative agri-food systems. Similarly, Yakovleva & Flynn (2009) find that interaction between organic and conventional systems in the UK happens at two levels:

- On one hand organic operators link to national retailers to reach the consumers and, by doing this they adopt their same business principles.
- On the other hand, some small conventional producers adopt organic in order to raise their incomes according to price premiums for these products, whereas big conventional operators adopt organic as a strategy of diversification, to have a chance in the growing organic market.

Because of this involvement of organic with the conventional system, Yakovleva and Flynn (2009) argue that both systems are becoming similar, so the organic niche is losing its capacity to foster a structural change.

Horlings and Marsden (2011) consider that three conditions are necessary to allow alternatives to be scaled up, in particular:

- Diversity and context dependency of agricultural practices, which cannot be directly copied;
- Enabling policy;
- Re-direction of agricultural research, development and knowledge transfer: a more integrated and regionally and locally embedded approach to the performance and resilience of agricultural systems.

Some authors criticise this view of opposed paradigms of food production and consumption. For instance, Ilbery & Maye (2005) study six food supply chains and assess them according to sustainability criteria. According to their analysis, the differences between conventional and alternative are not always clear and there is no guaranty for sustainability in local food supply chains because of several reasons:

- Local and conventional food systems share many times the same input suppliers. Therefore, when talking about sustainable food systems the primary focus should not be on the primary producer but on the actors downstream.

- The economic imperatives make many local alternative producers use different supply chains, not only local but also long channels. It is usually the case when quality products are marketed outside the region.
- Although local supply chains are often based on trust and reciprocity relationships, there is always space for power relationships, inequalities, conflict and personal gain.

In summary, alternative food production and consumption patterns tend to present themselves as more sustainable than the conventional system. Some of the key aspects in which they base this assertion are more environmentally-friendly grown methods, such as low input agriculture, integrated crop management, organic agriculture; less kilometres from farm to plate: local / regional supply chains; and a more equal distribution of costs and profits between stakeholders along the value chain.

Not many works have been carried out in order to stringently evaluate the superior sustainability performance of alternatives in comparison to the conventional agri-food system. Nevertheless, it is clear that those alternatives try to address in a different way some of the most essential problems that challenge the sustainability of the conventional food system.

5. Conclusions

The process of modernization of the agri-food system may be described as a process of progressive capitalization, concentration and internationalization. Following Goodman et al (1987) two trajectories based on scientific and technological development guided the growing commercial integration and the strengthening of links between agriculture and industry: appropriationism and substitutionism.

Appropriationism refers to the fact that industrial capital takes elements of the rural production process to turn them into inputs. It is represented by mechanization, production of fertilizers and seeds, and some other more recent developments in the field of biotechnologies.

Substitutionism means that rural products are substituted for others of industrial origin. It is represented by developments in the area of chemistry.

Progressively, scientific developments in other industries were allowing the existence of new areas of capital accumulation upstream and downstream the farm, shaping the current dominant food system.

These industrial dynamics mean that innovation sources are mostly external to the farm. Therefore, the modern agri-food system was shaped according to a capitalist logic of mass production and mass consumption. In addition to the interests of private capital, agricultural science policies and public policies aimed at the agri-food sector had the increase of production as its main objective, thus reinforced these trends.

The modern agri-food system has the advantage of producing a wide range of food products never met by humankind. However, it has also several social and environmental consequences.

Firstly, farmers became just a simple link in a complex agri-food value chain, as providers of inputs. In order to adapt to the requirements of mass production, they had to adopt the last technological advances and increase their size in order to keep a decent living, whereas some others had to abandon their land. Secondly, and regarding knowledge, farmers became highly dependent on external, standard and codified knowledge, which worsen their weak position in the agri-food value chain.

Moreover, the hidden side of the modern agri-food system is represented by a wide range of environmental problems. The intensive use of biotic resources has consequences in terms of resource depletion; the intensive use of external inputs, usually based on non renewable resources, also has several impacts, in terms of resource depletion and environmental pollution.

Empirical studies show that it is difficult to make general statements about the environmental performance of the agri-food system. Different approaches and methodologies, system boundaries and products, as well as different objectives, usually lead to varied results. However, when looking at the life cycle of food products, it is possible to identify some general problems that question the sustainability of the system:

- In terms of GHG emissions, the agriculture stage is responsible for major N_2O and CH_4 emissions. Fossil fuels and refrigeration account for a great amount of CO_2 emissions along post-farm stages.
- Although agriculture production is usually the main source of impacts, if we take into consideration processing, transport and retailing together, they are responsible also for a similar or higher share of GHG emissions.
- Other indicators show that transport –especially domestic transport by road and shopping transport–, and packaging are also important sources of environmental impacts along the food value chain.
- It is worth noting that emissions along the supply chain also vary depending on the food product that is being analysed. Several authors coincide in the important environmental impacts of meat and dairy products in relation to other agricultural products (see e. g. Risku-Norja & Mäenpää, 2007; Risku-norja, 2008; Garnett, 2010).

What constitutes evidence is that environmental problems linked to the industrialized and globalized food system question its sustainability in the long term. The verification of many weaknesses –not only environmental but also socio-economic– lets room for alternatives. This is the reason why besides the dominant agri-food system there have emerged in the last few several decades, an alternative paradigm of food production and consumption, which defines itself as more sustainable.

The alternative paradigm of food production and consumption is based on different values, such as an environmentally-friendly approach to production, shorter supply chains where there is a more close relationship between producers and consumers, and a fairer distribution of costs and benefits along the value chain.

Although the literature reviewed does not allow to categorically assert that alternative food systems are more sustainable than the conventional food system, what is true is that alternatives represent a different approach towards food production and consumption that have some environmental concern at their heart, and at least they are not so dominated by the capitalist logic.

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