CHAPTER

TRANSITION TO A SUSTAINABLE AGRO-FOOD SYSTEM: THE ROLE OF INNOVATION POLICIES

4

P. Morone, L. Cottoni

Unitelma-Sapienza, University of Rome, Rome, Italy

4.1 INTRODUCTION

In this chapter, the way that innovation policies lead the system toward the adoption of a sustainable agro-food model is addressed. Firstly, the growing pressure exerted upon the agro-food sector as a consequence of the ongoing demographic and economic trends is addressed. Most notably, the world population is projected to increase by more than 2 billion people by 2050, and nearly all of this growth is forecast to take place in developing countries (FAO, 2015). At the same time, large and fast-growing economies—most notably India and China—will experience increasing wealth, with the number of people considered to be part of the "global middle class" (ie, with incomes between $6000 and $30,000 in PPP terms) projected to reach nearly 5 billion by 2030 (Kharas, 2010). This will lead to a growing demand for food and fiber to feed a growing population with a smaller rural labor force (due to the ongoing urbanization process). This trend could be complemented by a growing demand for feedstocks for a potentially huge bioenergy market (FAO, 2009).

All these changes call for a shift in the paradigm currently governing the agro-food system, allowing the introduction of a more sustainable approach, capable of providing the right answers to emerging challenges. This issue within the framework of transition theory (and, more specifically, sustainability transition theory) is addressed, allowing the identification of the change drivers within a coevolutionary framework where ecosystems, technologies, institutions, business strategies, and user practices coevolve within a multilevel (micro-meso-macro) perspective (Foxon, 2011). The chapter will then introduce some examples of innovation activities, which are effectively pushing the agro-food sector toward a sustainable transition, focusing mostly on the waste issue. The analysis begins by presenting an assessment of the major (mega) trends distressing the agro-food sector.

4.2 THE GROWING PRESSURE ON THE AGRO-FOOD SYSTEM

The growing pressure exerted by demographic and economic trends upon the agro-food system is posing new and unexpected challenges to be faced by most policy makers around the world. In order to understand how these challenges can be transformed into opportunities, the boundaries of the problem

Innovation Strategies in the Food Industry. http://dx.doi.org/10.1016/B978-0-12-803751-5.00004-0
Copyright © 2016 Elsevier Inc. All rights reserved.

should be clearly identified. As we proceed here, we identify three key areas of enquiry where the limits to growth[1] of the agro-food sector are identifiable: (1) the impact of population growth on food security and climate change; (2) the indirect land use change associated with the growing biofuel production; (3) the waste management issue stemming from growing global demand and production of food and manufactured goods.

4.2.1 POPULATION GROWTH, FOOD SECURITY, AND CLIMATE CHANGE

The continuous growth of the world population in the last decades (mainly due to the progress made in the medical sciences and to the "green revolution"[2] in agriculture) is putting serious pressure on the global agro-food system, with an increased global demand for food, arable land, and water resources. As of November 2015, the world population is estimated to be about 7.283 billion people,[3] and it is expected to reach 9.6 billion by 2050 (UN, 2014), exceeding 10 billion by 2100, with estimates ranging from 9.3 to 12.6 billion (Gerland et al., 2014).

At the global level, the highest growth rate of the world population was recorded in 1963 at +2.2% annually. Since then the growth rate steadily declined to the current 1.08% (CIA, 2015).[4] In spite of this generalized slowdown in the growth of the world population, some countries in Sub-Saharan Africa and Asia are still growing at a pace above 2%. Moreover, most of these countries are expected to register a significant increase in GDP per capita, with 2 billion people expected to join the so-called new "global middle class"—defined as those earning between US$6000 and US$30,000 a year on a purchasing power parity basis—by 2030. As new wealthy consumers will have higher demand for food, ceteris paribus the prices of agriculture commodities are likely to increase sharply, thus endangering food security for those who cannot afford high prices for food (Wilson and Dragusanu, 2008).

There is no clear definition of food security. However, there are at least three widely accepted definitions of it. According to the 1974 World Food Conference, food security is defined as "the availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices." The 1996 World Food Summit defined it as the situation that exists "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." On the other hand, the World Health Organization[5] defines food security as the status in which "all people at all times have both physical and economic access to enough food for an active,

[1]As most readers know, this is the title of the challenging and path-breaking study conducted in 1972 by the Club of Rome. In their study the authors created a computing model that took into account the relations between various global development trends and produced computer simulations for alternative scenarios. Part of the modeling entailed different amounts of possibly available resources, different levels of agricultural productivity, birth control, and environmental protection. Most scenarios resulted in a steady growth of the population and of the economy until a turning point predicted to be reached around 2030. Only drastic measures for environmental protection proved to be suitable to change this trend, and only under these circumstances (ie, proactive environmental policies) did the Club of Rome manage to calculate scenarios in which both world population and wealth remain at a constant level.

[2]The Green Revolution refers to the massive spread of new technologies, occurring mostly in the middle of the 20th century, which led to marked increases in agricultural production worldwide associated with the introduction of modern or high-yielding crop varieties (Evenson and Gollin, 2003).

[3]http://www.census.gov/population/international/.

[4]CIA (2015) https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html. Retrieved December 2015.

[5]http://www.foodandenvironment.com/2013/01/basic-concept-of-food-security.html.

healthy life (…); the ways in which food is produced and distributed are respectful of the natural processes of the earth and thus sustainable (…); both the consumption and production of food are governed by social values that are just and equitable as well as moral and ethical (…); the ability to acquire food is ensured (…); the food itself is nutritionally adequate and personally and culturally acceptable (…); and the food is obtained in a manner that upholds human dignity."

Building on these complementary definitions, we can observe how food security has at least four intertwined dimensions: availability, access, utilization, and stability.[6] Food *availability* is related to the supply of food, food *access* to the affordability for the households and individuals, *utilization* refers mainly to the safety and quality of the food and its preparation, and, finally, *stability* is linked to the possibility to have a stable food supply.

The concept of food security is obviously a socioeconomic one, so it can be measured through various indicators such as per capita daily caloric intake. Moreover, questions of food security (and its countermovement of food insecurity) are deeply rooted into poverty and underdevelopment issues. Currently, the international community is intensifying cooperation in order to tackle this issue (eg, Millennium Development goal no. 1), identifying the main obstacles for the achievement of food security as: water scarcity, soil degradation, poverty and scarcity of capital, pests and diseases, and ineffective public sector policies. This trend is even more severe considering that arable lands per capita are expected to decline sharply within the next decades (Bruinsma, 2009), hence, requiring a notable increase in productivity in order to satisfy the growing food demand. All of this will magnify the already significant human impact on the environment. In the particular case of the agro-food system, the negative impact on the environment can occur through contaminating pollutants, soil erosion and degradation, hazardous and/or unnecessary waste, deforestation, depletion of water resources, and overexploitation of other natural resources. This might have several consequences, also economic ones, considering that a severe degradation of the environment can, by all means, undermine economic growth in the long term (Caldwell et al., 1997).

Climate change is another major area of concern highly related to these socioeconomic issues. Indeed, often world regions that are more vulnerable to food insecurity are also highly exposed to climate change. At the same time, it is difficult to estimate the overall impact of climate change on the agro-food sector because there is a very complex network of relations between different factors that mutually affect each other, hence undermining the possibility to establish clear causal relations and making it difficult to elaborate models for the assessment of the impacts of climate change on the environment (Lohele, 2011).

Generally, climate change affects the agro-food sector both directly and indirectly. Direct effects are linked to modifications of the ecological conditions—a fact that might yield positive or negative effects. For example, in countries with lower temperatures or a humid and temperate climate, a milder climate can enhance the productivity of crops both in terms of quality and quantity. However, higher temperatures can severely damage crops in dry zones. Another way by which climate change might affect the agro-food sector is through the increased occurrence of extreme adverse climate events worldwide (including droughts, flooding, storms, etc.). These rapid changes in climate conditions can negatively affect the yield of crops. The effects of adverse events can be partially mitigated by higher investments in better and safer storage facilities or in improving the irrigation system in areas at risk of drought. However, these mitigation policies are costly, meaning that the poorest areas, which experience the

[6]http://www.fao.org/fileadmin/templates/wsfs/Summit/Docs/Final_Declaration/WSFS09_Declaration.pdf.

highest rates of food insecurity (eg, some countries in Sub-Saharan Africa and south Asia) are also likely to be more vulnerable and less able to mitigate the adverse effects of climate change.[7]

Indirect effects are related to a series of pain chains that are potentially disruptive not only for the agro-food sector but for the whole economy. The first pain chain consists of the following steps: increased extremely adverse events in food insecure regions lead to malnourishment, which in turn worsens the health of the affected populations, resulting in a substantial decrease in economic productivity and in exacerbated poverty. Another negative outcome of climate change is a more intense exploitation of the soil; in order to face a fall in crop productivity due to climate change–related disasters, farmers will need more land that was otherwise preserved (Steinbuks and Hertel, 2016). Also, an increase in winter temperatures affects the odds that many agricultural pests will survive the winter, thus attacking the crops during springtime.[8]

4.2.2 FOOD CROPS VERSUS OTHER LAND USE

The competition for land is a recent trend in the agro-food sector. Nonetheless, its overall impact (including also a theoretical increase in food prices) is not easy to estimate, also because the competition for land is strongly related to the question of crops that are purposely grown for the production of biofuels. The backbone of this competition is a phenomenon called indirect land use change. In other words, when feedstock used for the production of biofuels are food commodities, there is a risk that land originally used for the production of crops is diverted to biofuels production. This may trigger a chain reaction. For instance, if corn prices soar, also milk, beef, pork, and cheese prices will eventually soar, as corn is used to feed the livestock. This will add further pressure on the whole agro-food sector and contribute to increases in food commodities prices (Morone and Cottoni, 2016).

However, soaring prices for food commodities is not necessarily caused by the competition for land brought on by the production of biofuels, if we consider that less than 2% of the world arable land is currently used to yield crops used for this purpose (Morone and Cottoni, 2016). Other factors can contribute to fluctuations in food commodities prices including crop productivity, consumers' and producers' expectations, financial speculation, precautionary demand, price of substitute and complementary goods, adverse weather conditions, energy costs, and inappropriate public policies.

On the other hand, it is worthwhile mentioning here that soaring prices for food can actually be an opportunity of economic growth for developing countries exporting agricultural commodities, as it may eventually lead to higher incomes and to a reduction in food insecurity. However, in the case of developing countries that are already affected by climate change, food insecurity, and poverty, this can be detrimental.

The pressure on food supply added by competition for land can be reduced through the enhancement of the "next-generation biofuels." In fact, advanced biofuels hold promise of an escape from their predecessors' food-versus-fuel conundrum (Fairlay, 2011). For instance, lingo-cellulosic feedstock (eg, trees, cereal straw, the organic of some municipal solid waste, sugar cane bagasse, forest residues, etc.) can be used for ethanol production, without the need for prime croplands, hence reducing the

[7]One innovative tool established for the purpose of mitigating climate change or helping affected populations is the "green bonds" issued by the World Bank. Through this tool, the World Bank raises funds from investors, issuing fixed income bonds in order to finance projects to mitigate the effects of climate change. http://treasury.worldbank.org/cmd/htm/WorldBank-GreenBonds.html. Retrieved December 2015.

[8]http://www.fao.org/docrep/004/y3557e/y3557e11.htm.

competition with food and fiber crops (Morone and Cottoni, 2016). Other innovative feedstocks for biofuels (such as micro- and macroalgae), although still not commercially viable, are the object of intensive scientific research (Morrison et al., 2014).

However, biofuels have been heavily criticized also from the purely "scientific" point of view (Searchinger and Heimlich, 2015) mainly because of their low efficiency in converting sunlight into energy. As a matter of fact, only 0.5% of the incoming solar radiation is converted into sugar via photosynthesis and only 0.2% in ethanol, in the case of Brazilian sugar cane. Searchinger and Heimlich (2015) recommended the use of photovoltaic cells that have an estimated conversion rate of solar energy into electricity of up to 16%, far greater than the 0.2% of the biofuels. In this way the competition for land can be strongly reduced, mitigating the pressures of the other megatrends. Moreover, as opposed to biofuels production, photovoltaic technology does not need prime land with good and fertile soils and plenty of water. However, there are some serious disadvantages also in the photovoltaic technology, including intermittency, difficult storage, expensive equipment, complex and expensive waste treatment, frailty (and insurance costs), and a long-term irreversibility of the process for the land in which they are installed (up to 20 years or even longer).

Another issue that must be taken into account when considering the impact of land competition on the agro-food sector is the need to conserve land in order to offset greenhouse gas (GHG) emissions. In other words, with food demand soaring, deforestation will become harder to prevent. From this perspective, a transition toward a more sustainable agro-food production system is compulsory, not only because of the inherent finitude of the available land but also due to the need to avoid a skyrocketing food demand created by the rise of the new "global middle class" and a more intense deforestation.

A final issue to be considered here relates to fiber and timber production. With the rising global middle class these industries present a tough competitor for land to food producers. Yet, for both food and fiber producers this pressure can be minimized if an efficient system of waste management and recycling—an area of enquiry where we now turn our attention—is created.

4.2.3 MANAGING AND AVOIDING WASTE

Waste can pose risks to the agro-food sector (and the environment, in general) in various ways. For example, illegal landfills can degrade and contaminate the soil; moreover, if one-third of the food produce worldwide goes to waste, this is responsible for unnecessarily adding 3.3 billion tons of GHGs to the planet's atmosphere (UNEP, 2013). The difficulties may well become even tougher, considering population increases, economic growth, and the related rise in mass consumption. Although a huge increase in the quantity of solid waste is expected, waste management is not just a quantitative issue but rather a qualitative one, as increasingly it contains new and complex substances (eg, electronic equipment waste, chemicals, etc.) that contribute in various and unpredictable ways to the degradation of the environment. Moreover, waste is not only a major issue in the agro-food system but also a potential threat to human health and a menace to the existence of some ecosystems (contributing to about 5% of global GHG emissions[9]).

Bearing this in mind, minimization of the impact of waste is an urgent challenge for policy makers all over the world. The first steps to be undertaken in this direction are waste avoidance and minimization. At the same time, unavoidable waste should be treated in a manner that is the least harmful for human health and the environment.

[9]http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_8_Waste.pdf.

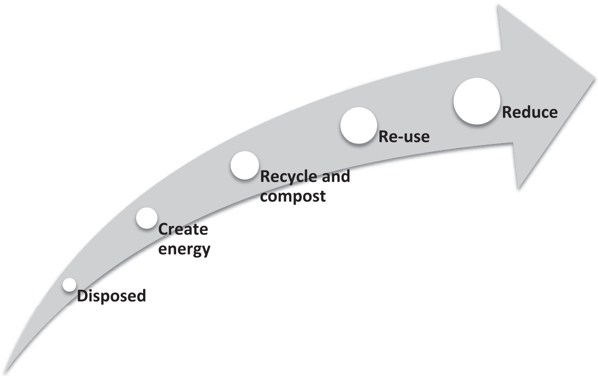

FIGURE 4.1

Waste hierarchy.

Adapted from http://www.target45plus.org.uk/waste-minimisation/waste-hierarchy/.

Recently the Environmental Protection Agency of New South Wales, Australia, approved[10] an innovative plan to pursue the highest standard of efficiency in waste treatment and minimization. The vision underlying this new policy strategy (Waste Avoidance and Resource Recovery) suggests that the primary goal is to enable local communities to improve environment and community well-being by reducing the environmental impact of waste and using resources more efficiently. Using resources efficiently and keeping materials circulating in the productive economy should, in turn, also help to create jobs and boost economic growth. This view of waste management is functional to the transition toward a circular economy, a new conceptualization of the socioeconomic system in which every resource is used with the maximum efficiency. The reverse pyramid (see Fig. 4.1) describes the waste hierarchy that is needed in order to minimize the pressure of the waste on the environment and human health.

Other solutions to improve the process of waste management can be: conservation of the resources (also avoiding excessive consumption), energy recovery from residual waste, systematized collection and segregation (in particular, of materials containing hazardous substances), reuse and recycling (avoiding the disposal of the waste in a landfill considered a destination of last resort), and improving existing processes and infrastructure for waste collection and treatment.

However, proper waste treatment or recycling can be commercially unattractive, in particular in poor countries, where innovative processes to treat waste are lacking or absent. Due to the quantity and complexity of the issues at stake, an increase in private investment would certainly help to create significant positive externalities for the population. At the same time the benefits for the investors are not guaranteed, and this can be a serious problem for the modernization and innovation in a sector where public investment is insufficient. In order to solve the problem of the scarcity of private investments, new instruments for funding innovation are being devised. The most notable examples are microfinancing and hybrid financing (combined debt and equity). The "Participatory Sustainable Waste Management Project" established in Brazil in 2006, for example, created microcredit funds from donations (Hogarth, 2009). These funds are used as working capital for financing waste transportation and

[10]http://www.epa.nsw.gov.au/resources/wastestrategy/140876-WARR-strategy-14-21.pdf.

waste-related emergency responses. The funds are also used to extend loans to waste pickers who will repay their loans after receiving payment from recycling depots (UNEP, 2011).

Other policy instruments used worldwide for the improvement of the sector include subsidies (those generating positive externalities), taxes and fees (with the aim, for instance, of discouraging behavior that might trigger negative externalities), and regulations (imposing, for instance, standards or targets for recycling; banning certain items such as plastic bags, etc.) (UNEP, 2011).

Along with these lines of intervention, another way of improving the use of the resources is the "pay as you throw" (PAYT) scheme, charging weight-based disposal fees. This solution can incentivize considerably more environmentally friendly behavior. A variation of PAYT is the "volume-based waste fee" scheme (widely used in South Korea[11]), implemented through prepaid garbage sacks in which residual waste is disposed of while recyclables are collected without paying any charges. Also in South Korea, policy makers have been planning innovative solutions including providing user cards and recycling bins with radiofrequency identification chips in order to record and weigh discarded products, billing the user monthly on the basis of the waste produced. These measures have generated significant reduction in the produced amount of waste (UNEP, 2011).

Among the different types of waste, food waste is a major problem in the agro-food sector because it prevents an optimal utilization of resources, thus exacerbating the pressures of the megatrends previously analyzed. The analysis developed so far shows how a new model is much needed to ensure both economic and environmental sustainability. A conceptual framework will highlight how a transition from an unsustainable sociotechnical regime toward a sustainable one might occur. This will also allow us to frame the role played by policy makers in the transition toward sustainability.

4.3 TRANSITION THEORY AS A CONCEPTUAL FRAMEWORK FOR SUSTAINABILITY

Sociotechnical transitions are a prominent issue in the economic and policy analysis fields. This topic is so widely studied because it allows understanding the major economic, historical, and societal changes throughout economic history. Based on a growing transition literature, we will present the approach used and identify its elements vital to a functional system analysis. To this purpose we will refer to an analytical framework developed specifically to study complex, sociotechnical systems, ie, the multilevel perspective (MLP). According to the heuristic model, transitions are the outcome of interactions between three levels: landscape, regime, and niche.

4.3.1 SOCIOTECHNICAL TRANSITION AND THE MULTILEVEL PERSPECTIVE

A technological transition is a phase in which an old technology and a new one coexist, and the new technology takes over and replaces the old one. When a new technology is first introduced in the technological array, it might not be immediately ready to compete in the mainstream market. For instance, as shown in Fig. 4.2, it took almost 60 years for the steam engine to overcome sailing, with a coexistence period lasting for more than 20 years.

[11] http://www.asiatoday.com/pressrelease/south-koreas-food-waste-solution-you-waste-you-pay. Retrieved December 2015.

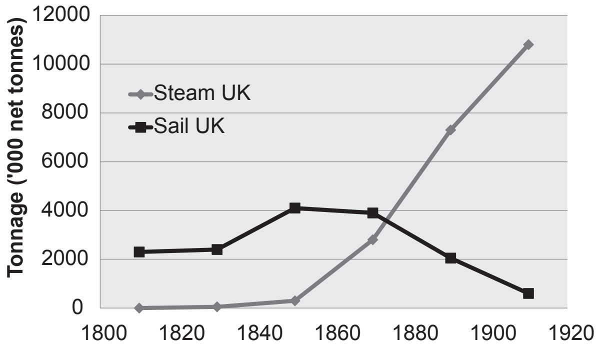

FIGURE 4.2

Tonnage of steamships and sailing ships in Britain.

Adapted from Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways, Research Policy 36(3), 399–417.

The MLP is a heuristic model, which covers three levels of analysis: the landscape (macrolevel), the sociotechnical regime (mesolevel), and the niche (microlevel). Technological transitions can be explained through the interaction among these three levels as the transition basically entails a shift from an incumbent sociotechnical regime to a new one, which is nurtured in the technological niche and prompted at the landscape level. Landscape and niches are *derived concepts* "because they are defined in relation to the regime, namely as practices or technologies that deviate substantially from the existing regime, and as external environment that influences interactions between niche(s) and regime" (Geels, 2011).

MLP helps understanding and analyzing complex and nonlinear phenomena such as historical and structural changes, including technological transitions, using a multidisciplinary and multidimensional perspective. Hence, MLP is not just about economics or competing technologies; it involves many other areas of investigation placing the transition process in a well-defined societal space and historical context.

In this framework, niches are the locus of innovation. A niche is like an incubation room in which new and emerging technologies have a space that protects them from competition and pressures of the selective process taking place in mainstream markets.[12] Usually rules and procedures in the niches are flexible and not formalized in order to facilitate the emergence of innovation. At the same time, the niche space is highly unstable and characterized by the coexistence of several (and often alternative) technological niches, which usually lack coordination between them and in competition among each other. However, not every niche can survive for a long time, and only few of them will get to a point where they will really challenge the incumbent sociotechnical regime. For this to happen, a technological niche should be sufficiently developed so that it reaches maturity.

Niche maturity level can be categorized into three developmental stages: embryonic, proto-niche, and fully developed (Lopolito et al., 2011). In order to assess maturity, the strategic niche management

[12]Initially, new technologies may face several problems such as high costs and low efficiency. Hence, innovation niches are an essential element of the transition, where emerging and promising technologies are nurtured, shielded, and empowered in a protected space.

approach proposes three niche mechanisms: (1) willingness (level of sharing expectations among niche actors), (2) power (based on the presence of powerful actors, namely those carrying valuable assets for niche development), and (3) knowledge (based on the density of knowledge present in the system and its flows). Maturity is reached whenever the three mechanisms coexist.

In this model transition occurs whenever a pressure at landscape level destabilizes the regime, thus creating a window of opportunity for pioneering niche technology to enter in the mainstream market. In the MLP the landscape is the least defined layer, often considered a residual concept. The landscape contains a wide and heterogeneous spectrum of factors, for instance, commodity prices, wars, environmental problems, and demographic and political issues (Geels and Schot, 2007). It is not always easy to understand whether a factor belongs to the landscape or to the regime as the literature does not provide us with clear rules to distinguish among them. As mentioned, coming from the landscape on the regime can create a window of opportunity for the technological niches. For example, high oil prices can create an opportunity to newly developed technologies in the field of nonfossil fuels.

Although possible, and sometimes desirable, destabilizing the regime is not something that can easily happen. This is mainly because the incumbent regime is a rather stable configuration, defined as a bundle of "structures made by a co-evolutionary accumulation and alignment of knowledge, investments, objects, infrastructures, values and norms that span the production-consumption divide and constitutes the prevailing mean for realizing key societal functions" (Smith et al., 2010, p. 441).

As pointed out by Geels (2002), the sociotechnical regime consists of a number of dimensions: (1) technology, (2) user practices and application, (3) the symbolic meaning of technology, (4) infrastructure, (5) policy, and (6) technoscientific knowledge. These elements are highly interlinked, making the regime a very stable reality. Regime stability is further reinforced by the so-called *lock-in effect* (Arthur, 1989), deriving from the following factors: learning by using (which accelerates technological improvements), network spillovers (the more widely a technology is used, the more applications are developed for it, and the more useful it becomes), economies of scale (which reduce unitary price), increasing informational returns (linked to learning by using, whereby the increased number of users, knowing more about the technology, makes it easier for others to learn about the technology), and development of complementary technologies (which both reinforce the position of the technology and make it more useful).

While the stability of the regime is essential for its endurance, it must also have a certain degree of flexibility in order to cope and withstand the pressure applied on it; this feature is defined as adaptive capacity. As mentioned, pressure comes both from the niches and the landscape levels, and regime actors have to use whatever is at hand in order to defend their position. The more intense or destabilizing these pressures are, the greater the amount of resources that have to be deployed to protect the regime. Regimes with a high level of adaptive capacity are more likely to survive and not be substituted for by innovations coming from the niches or destabilized by a changing landscape.

4.3.2 SUSTAINABILITY TRANSITIONS

Not every transition is a leap toward the achievement of sustainability. In the past, many transitions actually contributed to the destruction of the environment, although they led to huge economic progress. Yet, considering current environmental and socioeconomic trends, future transitions will have to address both the issue of sustainability and economic efficiency. Hence, there is a growing interest in the so-called "sustainability transitions" literature.

Sustainability transition can be defined as a long-term, multidimensional, and fundamental transformation process through which an established sociotechnical system shifts to more sustainable ways of production and/or consumption (Geels and Schot, 2010). The theoretical framework (analyzed in Section 4.3.1) is the same for both sociotechnical transitions and sustainability transitions, even if the latter can have some specific different features.

As pointed out by Smith et al. (2005), sustainability transitions can be goal oriented (and not emergent, like in the past) since they need to address specific challenges concerning issues of environmental long-term sustainability (climate change, depletion of natural resources, pollution, etc.). The main obstacle to the sustainability transitions is ensuring a commercial viability without needing the overriding support of the public sector. Sustainability can certainly bring more benefits to all; however, these benefits for the investors can be, in comparison, smaller than those generated by investing in incumbent technologies.

Goal-oriented sustainability transitions are difficult to achieve because they involve long development times, uncertainty about market demand and social advantages, scarce capital from private investors, presence of established lock-ins and path dependences in the current sociotechnical regime, and difficulty in coordinating among different institutional actors involved (government, private enterprises, researchers and scholars, other social actors, etc.). Moreover, governing transitions through public policies may not be easy as the more the sociotechnical regime is stable, the more will it resist the intervention of the public sector. Trying to impose a sustainable transition through traditional policy tools may actually have adverse effects. For instance, a cap-and-trade system in order to reduce emissions can have unintended and unforeseen consequences.[13] The regime, in fact, is influenced by a large array of factors that affect each other in unknown ways, so it is difficult for the policy maker to understand how a sustainable transition can be unlocked.

Goal-oriented sustainable transitions require extra policy efforts in order to steer the change into the desired direction. In this regard, the megatrends discussed in Section 4.2 are encouraging such efforts, determining an unprecedented pressure exerted by the landscape upon the unsustainable sociotechnical regime. As a case in point, the acknowledgment of climate change as a global problem is likely to add pressure on the incumbent regime, thus creating new opportunities for sustainable technologies under development in the niches. Indeed, the recent agreement reached at the United Nations Climate Conference in Paris in December 2015 marks an unprecedented political recognition of the risks of climate change and is likely to open a window of opportunities for new, more sustainable technologies to replace the incumbent fossil fuel–based economy.[14]

---

[13]It is clear that a binding cap on emissions will restrict the supply of all energy-intensive goods. This implies that the global price of these goods must increase, and therefore production abroad will increase, which will lead to higher emissions abroad. This effect is called "carbon leakage," and a recent study based on a large general-equilibrium model concludes that about 40% of any reduction in the production of energy-intensive goods in the European Union would be offset by higher production abroad (Veenendaal and Manders, 2008).

[14]In fact, according to John Schellnhuber, head of the Potsdam Institute for Climate Impact Research, delivering a warming of "well below" 2°C requires that global carbon dioxide emissions peak "well before 2030" and "be eliminated as soon as possible after 2050." That would represent a rate of "decarbonization" far greater than the world has yet seen. http://www.economist.com/news/international/21683990-paris-agreement-climate-change-talks. Retrieved December 2015.

4.4 TURNING CHALLENGES INTO OPPORTUNITIES: FROM WASTE TO WEALTH

Food waste and food losses are key issues to be addressed to allow the development of a more sustainable agro-food system. Although there are no official definitions of "food waste" and "food loss," the most accepted meaning of food waste is "all food produced or purchased that is discarded by humans" (Gallo, 1980), while the nature of food loss is currently being investigated (Griffin et al., 2009). Until 2000 in the European Union food waste was defined as "any food substance, raw or cooked, which is discarded, or intended or required to be discarded."[15] Since 2000, however, there is no official definition of food waste, but there are several categories of waste and each of them is subjected to a different European legislation. In 2014 the European Commission, while defining the targets and the standards in a proposal of a legislative act relating to waste management, defined food waste as food (including inedible parts) lost from the food supply chain, not including food diverted to material uses such as biobased products, animal feed, or sent for redistribution.[16]

The lack of an official definition prevents the collection of homogenous and comparable data, making the research about these phenomena quite difficult. According to a report of the Food and Agricultural Organization of the United Nations (FAO (2011)) , on a global basis food waste was estimated at 1.3 billion tons per year.[17] In the United Kingdom, the Waste Resources Action Program distinguishes three categories of food waste: avoidable (when the food is discarded even though it is perfectly edible and suitable for human consumption), possibly avoidable (eg, when the food discarded can become edible if prepared in a different way), and unavoidable (when the food discarded is not edible).

In Section 4.2, the question of waste production as a source of pressure on the socioeconomic and environmental systems was discussed. Such pressure is caused by the growing amount of municipal solid waste (a consequence of population growth and the ongoing urbanization process) and the hazardous compounds (and the GHGs) released into the environment, posing serious threats to the health of humans and other species. Food waste itself is not a threat to human health, however, it can indirectly affect it by reducing the efficiency of the agro-food system. Hence, as stated by the FAO Director-General José Graziano da Silva, "[i]n addition to the environmental imperative, there is a moral one: we simply cannot allow one-third of all the food we produce to go to waste, when 870 million people go hungry every day."[18] In this regard, food waste is primarily a socioeconomic issue rather than a mere ecological concern. Food waste and losses are severe obstacles to food security for poorly nourished and undernourished people of the world. Moreover, reducing food waste relieves the competition for land and water making these resources available for other valuable uses.

Through proper policies purposely designed, it is possible to improve the overall efficiency of the whole supply chain in the agro-food sector. An efficiently engineered supply chain can be a viable instrument to relieve food insecurity in both developed and developing countries. A more efficient supply chain can bring lower prices to consumers and lower costs for the firms. Here, the primary tool to mitigate the entity of food waste is prevention at every level: consumers, for example, can avoid

[15] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31975L0442. Retrieved December 2015.
[16] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014PC0397. Retrieved December 2015.
[17] In the United States about 95% of food waste ends up in landfills (Environmental Protection Agency: http://www.epa.gov/recycle/reducing-wasted-food-home. Retrieved December 2015.
[18] http://www.unep.org/newscentre/Default.aspx?DocumentID=2726&ArticleID=9611. Retrieved December 2015.

discarding perfectly edible food for mere aesthetic reasons, or limit overconsumption and over storage; producers, on the other hand, can engage in a more careful life cycle analysis of products, making the supply chain more efficient using new technologies.

In fact, food waste and loss occurs throughout the whole supply chain. According to the FAO (2013), 54% of the world's food wastage occurs "upstream" during production, postharvest handling, and storage, while 46% happens "downstream," at the processing, distribution, and consumption stages. As a general trend, developing countries suffer more food losses during agricultural production (mainly due to the poor availability of appropriate and functioning storage facilities), while food waste at the retail and consumer level tends to be higher in middle- and high-income regions. In developed countries 42% of food waste is produced by households, 39% by the food industry, 14% by the food service industry, and 5% in retail and distribution (Mirabella et al., 2014). As a matter of fact, the later a food product is lost along the chain, the greater the environmental consequences are, since the environmental costs incurred during processing, transport, storage, and cooking must be added to the initial production costs.

Bearing this in mind, changes must be introduced at every level of the human food chain, including farmers and fishermen; food processers and supermarkets; local and national governments; and individual consumers. Thus, the aim is to prevent food wastage from happening in the first place and to reuse or recycle it when prevention is not possible. This process can be realized through the establishment of a "food recovery hierarchy."[19] Food recovery contributes to convert waste into wealth, thus enhancing the efficiency of the agro-food system through the valorization of the resources that otherwise would have been wasted. This vision of food waste is deeply linked to the "circular economy" and the "zero-waste economy" concepts.[20]

Higher in the food recovery hierarchy are source reduction and food rescue to feed the most food insecure. Recovery for other valued uses, such as to feed for animals or for industrial uses, are next on the list, followed by composting. Incineration and landfill are the least preferred options. Moving along this line, we shall now consider two examples of actions aiming at (1) source reduction and (2) food rescue.

4.4.1 FOOD SHARING AS A STRATEGY FOR SOURCE REDUCTION

In recent years, a number of prevention and mitigation measures have been put in place to reduce food waste. It should be noted, however, that these measures themselves are not without cost (FAO, 2014). As an alternative to more traditional policies, Belk (2007, p. 126) suggests looking at the sharing economy approach, which involves "the act and process of distributing what is ours to others for their use and/or the act and process of receiving or taking something from others for our use." Hence, a viable and possibly less costly solution could come from the application of this type of approach.

---

[19]Environmental Protection Agency: http://www.epa.gov/sites/production/files/2015-08/fd_recovery_hierarchy_lg.jpg. Retrieved December 2015.

[20]A zero-waste economy entails also recycling but actually goes beyond it by taking a systemic and holistic approach to the vast flow of resources and waste that is produced by human society. A zero-waste approach aims at maximizing recycling, minimizing waste, reducing consumption, and ensuring that products are made to be reused, repaired, or recycled back into nature or the marketplace.

Food sharing practices were first documented by anthropological studies on primitive and contemporary hunter–gatherer societies (see among others Peterson, 1993; Hunt, 2000; Ziker and Schnegg, 2005; Jaeggi and Gurven, 2013). To avoid wasting parts of the hunted animal (those that the hunter and his household would not be able to consume by themselves), the meat is shared. Although these nomad societies are based on egalitarian political organization, their practical purpose is still suitable to the nonegalitarian sedentary society we live in. That is, people share food to avoid unnecessary resource waste.

Currently, there is a renewed interest in food sharing and a wide range of successful initiatives to this aim are spread across European and American countries (see Ganglbauer et al., 2014). A public debate has been launched to discuss the way they may contribute to food waste reduction, with benefits not only for the environment but also in economic terms for household savings.

4.4.2 FOOD BANKS AS A STRATEGY FOR FOOD RESCUE

Over the last 30 years food banks—for the redistribution of donated and surplus food—have established themselves as one of the fastest-growing charitable industries in high-income countries (Riches, 2002), emerging in response to the growing twin problems of food insecurity and food waste. Food banks rely on schemes whereby voluntarily given away food (that otherwise would be lost or wasted) is redistributed to those who need it. This strategy can be applied at the production stage with crops that otherwise would go unharvested, at the manufacturing stage with production surplus, and at the distribution and market stages with food left unsold at stores and markets.

At the production stage, there are several reasons for which edible grains, fruits, and vegetables remain in the field. For instance, food might go unharvested if the price of a given crop is too low to even pay for the labor required to pick that crop and the transport costs associated with selling it. In such cases, it makes more sense for the farmer to let that food be lost. Other reasons for which crops may not be harvested include weather or pest damage, imperfections relating to shape, size, and color, etc. At the manufacturing stage, a surplus amount of food might be produced when an order placed by a retailer is reduced/canceled, while at the market stage, surplus food might be generated when a store purchases too much of a certain item that then approaches or goes past the “sell-by” or “display until” date printed by the manufacturer. For instance, fresh-cooked meals at food retail stores that are unsold at the end of a day are typically thrown away (Lipinski et al., 2013).

The main obstacles to food redistribution are related to transportation, legal, and economic factors. For instance, farmers and stores with surplus food might not be physically close enough to food banks to make the transportation of unused food an economically viable option. On the legal side, potential food donors may be concerned about the legal repercussions should the food be unsafe and its recipients suffer health consequences. As for economic questions, as already mentioned, it might be prohibitive for a farmer to harvest and sell a type of food on the market, let alone donate it. In terms of possible policy measures, there are different alternatives that can be considered. Although the transportation obstacle, for instance, can be rather difficult to address, it can be tackled by establishing additional food bank locations to shorten distances. On the other hand, in order to address legal difficulties, policy makers can pass “Good Samaritan” laws that limit the liability of donors in case redistributed food unexpectedly turns out to be somehow harmful to the consumer (Lipinski et al., 2013).

4.5 CONCLUSIONS

In this chapter, the key drivers to a sustainability transition in the agro-food sector were investigated. Firstly, the areas of pressure on the food system stemming mostly from the megatrends occurring at the outset were identified, ie, the demographic growth trends accompanied by the foreseen income and wealth increases expected over the next 35 years. These trends are most likely to generate a general increase in the demand for food and manufactured goods and, consequently, in pollution emissions levels (most notably CO_2, with great impact on climate change), intensification of land use (with the associated problems such as indirect land use change and deforestation), and increase in waste (an issue related both to the finitude of resources and natural elements and to the management and disposal of residues and waste).

All these call for a paradigm shift from the current unsustainable production and consumption model toward a new model where climate change issues, food security, and waste management are conceived unitarily and are simultaneously tackled. Building on the MLP and, most notably, on sustainability transition theory, we argued that such a change occurs when pressure exerted by landscape actors upon the regime and technological pressure exerted by innovation niches ready to replace the incumbent technological regime occur. This theoretical view stems directly from long-wave theory on technoeconomic paradigm (TEP) shifts (Freeman and Perez, 1988), in the sense that it is multidimensional and addresses structural changes. However, rather than focusing on entire economies and aggregate macroeconomic processes (which is what TEP aims at), the MLP concentrates on specific areas of transition (eg, energy, transport, agro-food systems, etc.) looking closely at the various groups, their strategies, resources, beliefs, and interactions (Geels, 2011).

These groups of actors have, therefore, a pivotal role in shaping the trajectory of the transition, stirring the change in the desired (sustainable) direction. In this sense, well-crafted innovation policy actions can accelerate the transition toward a sustainable agro-food model. As a case in point we considered two actions to be undertaken to reduce and rescue food wasted: food sharing and food banks. Both actions entail an innovative approach to food consumption, setting good examples and practices for the type of mind-set change needed to make a paradigmatic shift, turning problems into opportunities and waste into wealth.

REFERENCES

Arthur, W.B., 1989. Competing technologies, increasing returns, and lock-in by historical events. The Economic Journal 99 (394), 116–131.

Belk, R., 2007. Why not share rather than own? Annals of the American Academy of Political and Social Science 611, 126–140.

Bruinsma, J., 2009. The resource outlook to 2050: by how much do land, water and crop yields need to increase by 2050? Food and Agriculture Organization of the United Nations. Economic and Social Development Department.

Caldwell, L.K., Bartlett, R.V., 1997. Environmental Policy: Transnational Issues and National Trends. Quorum Books, Westport, CT.

Evenson, R.E., Gollin, D., 2003. Assessing the impact of the green revolution, 1960 to 2000. Science 300, 758–762. http://dx.doi.org/10.1126/science.1078710.

Fairley, P., 2011. Introduction: next generation biofuels. Nature 474, S2–S5. http://dx.doi.org/10.1038/474S02a.

FAO, 2009. The Market and Food Security Implications of the Development of BioFuel Production Background document for the FAO Committee on Commodity Problems 67th session. Rome.

FAO, 2011. Global Food Losses and Food Waste – Extent, Causes and Prevention. Rome. http://www.fao.org/docrep/014/mb060e/mb060e.pdf. Retrieved December 2015.

FAO, 2013. Food Wastage Footprint Impacts on Natural Resources. Rome. http://www.fao.org/docrep/018/i3347e/i3347e.pdf. Retrieved December 2015.

FAO, 2014. Mitigation of Food Wastage. Societal Costs and Benefits. Retrieved online at: http://www.fao.org/3/a-i3989e.pdf.

FAO, WFP and IFAD, 2015. The State of Food Insecurity in the World 2015. Rome.

Foxon, T.J., 2011. A co-evolutionary framework for analysing transition pathways to a sustainable low carbon economy. Ecological Economics 70, 2258–2267.

Freeman, C., Perez, C., 1988. Structural crisis of adjustment, business cycles and investment behaviour. In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds.), Technical Change and Economic Theory. Pinter, London, pp. 38–66.

Gallo, A.E., 1980. Consumer food waste in the United States. National Food Review 3, 13–16.

Ganglbauer, E., Fitzpatrick, G., Subasi, Ö., Güldenpfennig, F., 2014. Think globally, act locally: a case study of a free food sharing community and social networking. In: Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing, February 15–19, 2014, Baltimore, Maryland, USA.

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research Policy 31 (8–9), 1257–1274.

Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy 36 (3), 399–417.

Geels, F.W., 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Research Policy 39 (4), 495–510.

Geels, F.W., 2011. The multi-level perspective on sustainability transitions: responses to seven criticisms,. Environmental Innovation and Societal Transitions 1 (1), 24–40.

Gerland, P., Raftery, A.E., Ev Ikova, H., Li, N., Gu, D., Spoorenberg, T., Alkema, L., Fosdick, B.K., Chunn, J., Lalic, N., Bay, G., Buettner, T., Heilig, G.K., Wilmoth, J., 2014. World population stabilization unlikely this century. Science (AAAS) 346 (6206), 234.

Griffin, M., Sobal, J., Lyson, T.A., 2009. An analysis of a community food waste stream. Agriculture and Human Values 26 (1–2), 67–81.

Hogarth, R., 2009. Microcapital Story: Participatory Sustainable Waste Management Project Extends Microfinance to Informal Recyclers in Brazil. Available online at: www.microcapital.org Retrieved December 2015.

Hunt, R.C., 2000. Forager food sharing economy: transfers and exchanges. Senri Ethnological Studies 53, 7–25.

Jaeggi, A., Gurven, M., 2013. Reciprocity explains food sharing in humans and other primates independent of kin selection and tolerated scrounging: a phylogenetic meta-analysis. Proceedings of the Royal Society B 280, 20131615.

Kharas, H., 2010. The emerging middle class in developing countries. OECD Development Centre, Working Paper No. 285. Research area: Global Development Outlook.

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R., Searchinger, T., 2013. Reducing food loss and waste. World Resources Institute, Washington.

Loehle, C., 2011. Criteria for assessing climate change impacts on ecosystems. Ecology and Evolution 1 (1), 63–72.

Lopolito, A., Morone, P., Sisto, R., 2011. Innovation niches and socio-technical transition: a case study of biorefinery production. Futures 43, 27–38.

Mirabella, N., Castellani, V., Sala, S., 2014. Current options for the valorization of food manufacturing waste: a review. Journal of Cleaner Production 65, 28–41.

Morone, P., Cottoni, L., 2016. Biofuels: technology, economics and policy issues. In: Luque, R., Clark, J., Wilson, K., Lin, C. (Eds.), Handbook of Biofuels' Production: Processes and Technologies, Second ed. Elsevier.

Morrison, G.M., Parker, N.C., Witcover, J., Fulton, L.M., Pei, Y., 2014. Comparison of supply and demand constraints on U.S. biofuel expansion. Energy Strategy Reviews 5, 42–47.

Peterson, N., 1993. Demand sharing: reciprocity and the pressure for generosity among foragers, American anthropologist. New Series 95 (4), 860–874.
Riches, G., 2002. Food banks and food security: welfare reform, human rights and social policy. Lessons from Canada? Social Policy & Administration 36 (6), 648–663.
Searchinger, T., Heimlich, R., 2015. Avoiding Bioenergy Competition for Food Crops and Land. Working Paper - Installment 9 of Creating a Sustainable Food Future. World Resources Institute, Washington, DC. Available online at: http://www.worldresourcesreport.org. Retrieved December 2015.
Smith, A., Stirling, A., Bekhout, F., 2005. The governance of sustainable socio-technical transitions. Research Policy 34, 1491–1510.
Smith, A., Voß, J.-P., Grin, J., 2010. Innovation studies and sustainability transitions: the allure of the multi-level perspective and its challenges. Research Policy 39 (4), 435–448.
Steinbuks, J., Hertel, T., 2016. Confronting the food–energy–environment trilemma: global land use in the long run. Environmental & Resource Economics 63 (3), 545–570.
UN, 2014. The World Population Situation in 2014. A Concise Report. Department of Economic and Social A airs Population Division, ST/ESA/SER.A/354.
UNEP, 2011. Waste. Investing in Energy and Resource Efficiency. Available online at: http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_8_Waste.pdf. Retrieved December 2015.
UNEP, 2013. Food Waste Harms Climate, Water, Land and Biodiversity. Available online at: http://www.unep.org/newscentre/Default.aspx?DocumentID=2726&ArticleID=9611. Retrieved December 2015.
Veenendaal, P., Manders, T., 2008. Border Tax Adjustment and the EU-ets, a Quantitative Assessment, CPB Document No. 171. Central Planning Bureau, The Hague.
Wilson, D., Dragusanu, R., 2008. The expanding middle: the exploding world middle class and falling global inequality. Goldman Sachs, New York.
Ziker, J., Schnegg, M., 2005. Food sharing at meals: kinship, reciprocity, and clustering in the Taimyr Autonomous Okrug, Northern Russia. Human Nature 16 (2), 178–210.