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Review

Innovation in the Agro-Food Sector: From Technical Innovation-Centred Approaches to Sustainability Transition Processes

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Abstract

Innovation is a complex phenomenon and process involving translation of knowledge into new techniques, products, services. It is considered crucial for sustainable agriculture development and achievement of long-term food security. The review describes the diversity of innovation and relates it to agro-food sector. It also sheds light on different innovation models and explores their contribution to framing agro-food sustainability transitions. There are many variations in the use of the term 'innovation'. Typical distinctions encountered in the literature are incremental vs. radical innovation and product vs. process vs. organizational innovation. A significant feature of the development of modern innovation thinking has been a gradual broadening of innovation scope as well as more attention to sustainability. The scope of innovation was broadened to include soft (social/organisation) innovations besides hard/technical ones. In fact, the interest has shifted from technological innovation to disruptive niche innovations fundamental for socio-technical transitions. Moreover, as recognition of system complexity, frameworks such as the Innovation systems and the Multi-Level Perspective (MLP) were developed and promoted. However, despite positive innovation benefits, relationship between innovation and sustainability in the agro-food arena is far from straightforward. Therefore, focus is gradually moving from innovation process to its impacts in terms of sustainability and its contribution to sustainability transitions in agriculture and food systems.

Keywords:
innovation, innovation systems, Multi-Level Perspective, sustainable agriculture, sustainability transitions

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INTRODUCTION

Schumpeter (1934, 1942) is often identified as the first to feature innovation as a central driver of the economy. Since then the field of innovation has evolved dramatically so that nowadays there are different understandings and definitions of innovation (e.g. Menrad & Feigl, 2007; Organisation for Economic Co-operation and Development [OECD] & Eurostat, 2005; Sterrenberg et al., 2013; STEPS Centre, 2010), so that Shaver (2016) points out to a 'lack of definitional clarity'.

Innovation is widely recognised as a critical dimension of sustainable development as well as sustainable consumption and production (European Political Strategy Centre [EPSC], 2016). It has an essential role to play in meeting the interlinked challenges of environmental sustainability, poverty reduction and social justice (STEPS Centre, 2010; United Nations [UN], 2012). In fact, innovation is seen as a route to economic growth as well as to propose effective solutions to real problems such as poverty (STEPS Centre, 2010). The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009) highlighted that Agricultural Knowledge, Science and Technology (AKST) is crucial to address different sustainable development issues such as poverty and food insecurity. According to Leach et al. (2012), delivering the Sustainable Development Goals (SDGs) requires a radically new approach to innovation. Similarly, according to STEPS Centre (2010), moving towards innovation for sustainability and sustainable development requires a radical shift in how we think about and perform innovation. This implies a radical change in the whole innovation process that addresses the issues of direction of innovation, distribution of innovation costs/benefits and diversity of innovation pathways and perspectives. Direction, distribution and diversity issues are particularly relevant in agro-food systems.

Innovation has become a key issue in the discussion about the relation between agriculture and sustainability (e.g. FAO, 2012; European Innovation Partnership- Agricultural Productivity and Sustainability [EIP-AGRI], 2013; FAO, 2013; International Panel of Experts on Sustainable Food Systems [IPES-Food], 2015; Global Harvest Initiative, 2016) especially in the context of sustainable intensification. In general, the critical role of innovation to make agriculture not only more competitive but also more sustainable is widely admitted. Agricultural innovation is considered vital for meeting the challenges of agriculture development, adapting to climate change and improving food security (International Assessment of Agriculture, Knowledge, Science and Technology for Development [IAASTD], 2009; Inter-American Institute for Cooperation on Agriculture [IIAC], 2014; European Commission [EC], 2016; United Nations Conference on Trade and Development [UNCTAD], 2017). However, for agriculture to respond to future challenges, agricultural innovation will not only need to improve input use efficiency, but also to reduce waste and conserve scarce natural resources (OECD, 2011; FAO, 2017). Doing so, innovations and modern techniques can strengthen food system resilience, improve resource efficiency in agriculture, and secure social equity thus contributing to the achievement of sustainable food security (High Level Panel of Experts on Food Security and Nutrition [HLPE], 2017). Therefore; innovation can play an important role in transitions to sustainable food systems. Nevertheless, innovation and knowledge needed to make sustainability transition is often contested and inconclusive (Batie, 2008; Levin et al., 2012; Peters & Pierre, 2014).

This review paper provides an overview on the diversity of innovation and relates the different types and categories of innovation to the agro-food sector. It also introduces the Innovation systems approach as well as the Multi-Level Perspective (MLP) on transitions as frameworks that highlight the systemic nature of innovation and put it in the context of transitions towards sustainability.

Innovation types and categories

The literature contains many categorisations of innovation along many different dimensions. One survey by Garcia and Calantone (2002) found 15 different constructs for categorising

innovation from only 21 studies. In fact, there are many variations in the use of the term 'innovation'. These variations depend on, for example, where the innovation is located in the value chain (e.g. product, process or organisational innovation), the novelty of the knowledge underlying the innovation, or the extent of the economic/market impact of the innovation (Twomey & Gaziulusoy, 2014). Typical distinctions one encounters in the literature are incremental vs. radical innovation (Dewar & Dutton, 1986), evolutionary vs. revolutionary innovation (Tushman & O'Reilly, 1996), sustaining vs. disruptive innovation (Christensen, 1997), and product vs. process vs. organizational innovation (OECD, 1997). According to Stummer et al. (2010), innovations can be categorized according to innovation type (product, service, process, market), dimension (objective or subjective), scope of change (radical, incremental, reapplied), or how innovation was created (closed or open). The OECD and Eurostat (2005) distinguish product, process, marketing and organisational innovations. Agricultural innovation as well as innovation in agri-food can be classified using the same categories (Avermaete et al., 2004; Avolio et al., 2014). Technical innovations in agriculture can encompass both product innovation and process innovation.

Product innovationsare changes or additions to goods produced or services delivered (OECD & Eurostat, 2005). New production techniques that allow new product innovations can be developed (Wegner, 1991). Important attributes of product innovation include improving useful product properties, increasing quality, design change and environmental impacts reduction. Process innovations are changes to the way of goods production or services delivery (OECD & Eurostat, 2005). They could be seen as an investment in company resources, skills and competences (Hauschildt, 1997). Distinction between process and product innovations is not always clear-cut as they are often closely related. However, in general, product innovations are aimed at differentiation, while process innovations are driven by cost-reduction concerns (Martinez-Ros, 2000). In agriculture, product innovations often involve incremental improvements rather than radical changes (Grunert et al., 1997; Fortuin & Omta, 2009; Bayona et al., 2013); meanwhile, food firms are mainly process innovation oriented (Garcia Martinez & Burns, 1999; Batterink et al., 2006). Marketing innovations are related to the market activities of the firm, like customer satisfaction, respect of high quality standards, product diversification, etc. (OECD & Eurostat, 2005).

Organisational innovations are changes in an organization's structure, services, activities, processes or in its relationship with other stakeholders (OECD & Eurostat, 2005). They modernise or improve process and administrative organisation of a company (Pleschak & Sabisch, 1996). Examples of organisational innovations include a hierarchy levels reduction, and interface and cooperation problems solution. Social innovations concern changes in human resources management field within companies, such as providing employees with specific training (Eherer, 1994). They refer to the substantial improvement or development of new concepts, strategies, ideas, organizations (IIAC, 2014). More broadly, social innovations are defined as new ideas (models, services and products) that simultaneously meet social needs and create new social collaborations or relationships (Murray et al., 2010).

Avolio et al. (2014) provided a survey of product, process, organizational and marketing innovations in Italian agriculture (Table 1).

Incremental and radical innovations are often distinguished using one or both of the following criteria (Bell, 2012): the novelty of the knowledge base underlying the innovation and the scale and significance of the innovation consequences. Innovation may comprise radical improvements but usually consists of a continuous upgrading process involving a combination of technical, social and institutional changes (Pound et al., 2008). Radical innovations imply a high degree of novelty. Product innovations are generally considered examples of radical innovations as they often mean complex changes in different company fields and high market risk due to high financial expenditures (Kotler & Bliemel, 1999; Wittkopp, 2004). Incremental innovations do not create a monopoly position and are often characterised by constant

improvements of benefit-cost ratio for company or utility pattern for consumers (Pleschak & Sabisch, 1996; Bessau & Lenk, 1999). In addition to the concepts of radical innovation and incremental innovation there is also that of 'reapplied innovation' that refers to successful implementation of existing innovations in a new area (Baldwin & Curley, 2007).

Disruptive innovation is sometimes used as synonymous of radical innovation. The disruptive innovation (Christensen, 1997) and technological discontinuity (Anderson & Tushman, 1990) literatures look at interactions between new entrants and incumbents, but tend to focus only on technology and market dimensions. Technological change tends to proceed incrementally along fixed paths due to the risk reducing behaviour of companies. This phenomenon is known as path dependency of innovation (Arthur D. Little, 1989). Path dependency creates technological lock-in, which acts as a barrier against disruptive innovation (Nelson & Winter, 1982).

In moving from a single innovation, to a cluster, to a system of innovation, perhaps the most well-known taxonomy is the one developed by Freeman and Perez (1988) that distinguish between four types of innovation: incremental innovations, radical innovations, changes of technology systems, and changes in 'techno-economic paradigm' (cf. technological revolutions). The term 'system innovation' is commonly used in literature to refer to either of the last two categories of Freeman and Perez's typology. In most cases, the term covers not only product and process innovations but also changes in user practices, markets, policy, regulations, culture, infrastructure, lifestyle and management of firms (cf. Berkhout, 2002; Kemp & Rotmans, 2005; Geels, 2006). A feature of the last two innovation categories, which involve clusters or aggregation of innovations, is that they rely on both incremental and radical innovation. It is, therefore, a mistake to underestimate the importance of cumulative, incremental innovation in understanding of major transformative change (Twomey & Gaziulusoy, 2014). Indeed, the benefits of many radical innovations – including the automobile and airplane – have only been recognised through a series of supporting incremental improvements (Geels, 2005; Dolata, 2011).

Political and institutional innovations are also important drivers of changes in the agro-food system. Political innovation may be considered as the development of new public policies and political systems and is often strongly linked to processes of institutional innovation. Adequate policies are crucial in creating a favourable economic, social and institutional environment for innovation by developing a suitable support system, removing obstacles in regulatory frameworks, strengthening human capital and promoting research and access to information (OECD, 2012; OECD, 2013; Padilla-Péreza & Gaudin, 2014). In fact, the innovation process is affected by the institutional context (e.g. regulations, rules, incentives, R&D investments), economic environment (e.g. presence in the territory of potential clients and/or suppliers), social context (e.g. sharing and interaction among the territorial actors), technological environment (cf. technological level of the actors involved) (Klerkx et al., 2012). Institutional innovations (cf. Hargrave & Van de Ven, 2006) entail a change of regulations, standards, processes, models, institutional practices or relationships to improve the performance of an institution or system (OECD, 2011). Institutional innovations are also necessary to foster agro-food systems that promote more diverse local crop production and create more favourable landscape for the provision of ecosystem services. This requires new and innovative modes of food system governance at local, national and international levels (IAASTD, 2009). Institutional innovations - especially those pursuing collective action model of institutional and social change (e.g. Van de Ven & Hargrave, 2004) - are also relevant for linking sustainable agricultural practices with markets thus fostering transition towards sustainable agri-food systems (FAO & INRA, 2016; Loconto et al., 2017).

It is out of the scope of the present paper to provide an exhaustive overview on agricultural innovation. However, according to the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2017), there are several prom-

ising innovations in agro-food systems that can contribute to food and nutrition security such as precision agriculture (cf. drones and sensors in mobile devices), information and communication technologies (ICT), including big data (pooling together information on water, climate and weather, soils, crops), biofortification, climate-smart agriculture (technologies to capture CO_2 and/or to reduce greenhouse gas emissions), technologies to reduce losses and waste along the food chain, bio- and nanotechnologies, and mechanization. The most prominent, but also maybe challenging, innovations are perhaps found in the digital revolution and the rapidly evolving field of precision breeding and genomics (HLPE, 2017). As it can be seen, most of innovations listed above are technical/technological and that confirms the marginality of social innovation in agriculture.

The United Nations Conference on Trade and Development (UNCTAD, 2017) analysed recently the role of science, innovation and technology in addressing the four dimensions of food security, namely availability (e.g. improving agricultural productivity through breeding, soil management, irrigation), access, utilization (e.g. nutrition science), and stability (cf. adaptation to climate change, precision agriculture) (Table 2).

Ultimately, the real challenge in agriculture and food system seems not only to have relevant innovations but also to fill the 'innovation gap' by strengthening the capacity of farmers and rural populations to effectively access and use them (Wyckoff, 2016). In fact, innovation diffusion and adoption is a central theme in the agro-food sector (e.g. Avolio et al., 2014; Özçatalbaş, 2014). According to Rogers (2003), diffusion is a "process by which an innovation is communicated through certain channels over time among the members of a social system". Frederick and Webster (1969) describe a five-stage process of innovation adoption from awareness (being aware that the innovation exists) to interest (being interested in the innovation and looking for more information), evaluation (examining mentally the innovation using gathered information), testing (experimentation to test the innovation in real-world context) and, finally, adoption. Furthermore, Rogers (2003) suggests that adopters can be categorized into five groups: innovators, early adopters, early majority, late majority, and laggards. The author adds that factors affecting innovation adoption relate to personality, socio-economics and communication behaviours.

Innovation frameworks: from focus on innovation process to sustainability transitions

According to Osburg (2013), innovation theory has seen constant change of its focus over the last decades: concept of newness (1950s), management theory (1960s), demand side (1970s), process innovation (1980s), service innovations (1990s), and, more recently, open innovation and social innovation.

Over the last decades, a more nuanced and richer picture of innovation has emerged, with a wider set of implications for those hoping to assist, shape or direct innovation process. A significant feature of the development of modern innovation thinking, particularly in relation to sustainability, has been a gradual broadening of the scope of both problem framing and analytical framing (Smith et al., 2010). That is, first, the object of innovation has been extended from the 1980s focus on production technologies towards interest in the entire production and consumption system. Second, the analytical frames and considerations used to study innovation processes have been enlarged from a focus on the role of the inventor or price signals to include a much broader set of systemic issues that may affect innovation development. Key new ideas include appreciating the importance of actor networks; the role of institutions; the co-evolutionary nature of the technologies, institutions, social practices and business strategies; the role of feedback and path dependency in socioeconomic systems; and a greater understanding of the different types of knowledge and learning processes (Twomey & Gaziulusoy, 2014). Whereas neo-classical economics has a minimal understanding of institutions, evolutionary economics and modern innovation theory give institutions a central role in enabling, constraining and shaping behaviours and practices (Foxon et al., 2013).

Table 1
Examples of Different Types of Agricultural Innovations in Italy

Type of innovation	Examples
Product innovation	New crop varieties/animal breeds and/or new agricultural products
	New services related to multifunctional activities (e.g. agritourism, recreational, social and educational activities, handicraft, on-farm processing of products, aquaculture, off-farm contracting, gardening services, animal feed production)
Process innovation	Conversion to more environmentally-friendly farming systems such as organic farming
	Use of computerized crops/livestock management systems
Organizational innovation	Integration of renewable energy plants (photovoltaic or biomass plants) in farms
	Use of a computerized accounting system
	Use of e-commerce to purchase inputs from suppliers
Marketing innovation	Farm website
	Selling products through e-commerce
	Having an off-farm short marketing channel

Source: Avolio et al. (2014).

The atomistic nature of neo-classical economics model also under-appreciates the role of culture i.e. ideas, customs, and social behaviour (Ormerod, 1998).

Compared to the linear model, an important feature of the modern approach to innovation is the interactivity among agents and feedbacks between different stages of the innovation processes (Kline & Rosenberg, 1986). The complexity of interaction and interdependence occur between as well as within systems (Foxon et al., 2013) giving rise to a species of co-evolutionary process. A co-evolutionary approach to innovation is an overarching theme in modern innovation theory. In particular, analysing transition pathways calls for a co-evolutionary understanding of the development of technologies, institutions, social practices and business strategies (Brand, 2003;

Table 2
Examples of Future Challenges to be Addressed by Science, Technology and Innovation in Ensuring Food Security

Food security dimension	Challenges to be addressed by innovation
Food availability	Biotic stresses (pest, diseases, weeds, etc.)
	Abiotic stresses (soil salinity, climate variability)
	Improving crop productivity
	Improving livestock agriculture
	Water scarcity
	Soil degradation
	Need for precise integration, scheduling of inputs for increased yield
	Farming in urban environments
	Power and control-intensive operations
Food access	Post-harvest loss (storage, refrigeration, transport)
	Need for harvest and agro-processing equipment
Food use / utilization	Lack of nutritious foods, especially staple crops
	Lack of information on healthy diets
Food stability	Inability to predict when and how to farm
	Lack of financial mechanisms to ensure income

Source: UNCTAD (2017).

Geels, 2005; Foxon, 2008). Sartorius (2006) states that "co-evolution implies that successful innovation in general and successful sustainable innovation in particular, has to acknowledge the involvement of, and mutual interaction between, more than the mere technical and economic spheres". Therefore, to understand change dynamics, a co-evolutionary approach acknowledging interactions between all components of socio-technical system, as well as between innovation categories, is essential (Gaziulusoy, 2010).

In the last decades, there has been a shift from an innovation concept centred on research to innovation as a result of interactions among several actors that establish diverse networks and linkages (World Bank, 2006) in an innovation system. In fact, modern innovation theory recognises that innovation is a joint activity involving a large number of actors with different perceptions, interests, capabilities and roles.

Appreciation of the importance of actor networks is a key idea also in modern agricultural innovation field. In the mid-1980s, the concept of 'innovation system' (Table 3) was introduced. Innovation Systems (IS) theory is a heuristic framework that starts from the basis that it is not entrepreneurs or firms alone that innovate; rather, innovation occurs in the context of an entire system. According to the definition, an 'innovation system' is the combination of all institutional and economic structures that affects both the direction and the speed of change in society; hence, the concept, which emphasizes the co-evolutionary character of change processes, is a combination of evolutionary and institutional theories (Hekkert et al., 2007), spans the range of sectors, and takes factors into account beyond just technical change (Lachman, 2013). Knowledge (both tacit and explicit) is often claimed to be the most fundamental resource in an innovation system, while learning is the most important process (Lundvall, 2007; Wieczorek et al., 2012). There are different forms of learning: learning-by-doing (Arrow, 1962); learning-by-using (Rosenberg, 1976); learning-by-interacting (Lundvall, 1988); single loop and double loop learning (Argyris & Schon, 1978).

In the 1990s, variations of the innovation sys-

Table 3
Some Concepts Related to Innovation in Agriculture

Concept	Definition	Source
Agricultural innovation	Agricultural innovation is a socially constructed process. Innovation is the result of the interaction of a multitude of actors, agents and stakeholders within particular institutional contexts. If agricultural research and extension are important to agricultural innovation, so are markets, systems of government, relations along entire value chains, social norms, and, in general, a host of factors that create the incentives for a farmer to decide to change the way in which he or she works, and that reward or frustrate his or her decision.	IAASTD, 2009:560
Innovation system	A network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance. The innovation systems concept embraces not only the science suppliers but the totality and interaction of actors involved in innovation. It extends beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in novel and useful ways.	World Bank, 2006:vi–vii
Agricultural Knowledge and Information System	A set of agricultural organizations and/or people and the link and interaction between them engaged in such processes […] of knowledge and information with the purpose of working synergistically to support decision making, problem solving and innovation in a given country's agriculture or domain thereof.	Röling, 1990

tems approach were devised based on different system boundaries (Freeman, 1995; Jacobsson & Bergek, 2010): National Innovation Systems (NIS); Sectoral Innovation Systems (SIS) such as agricultural innovation Systems (AIS); Technological Innovation Systems (TIS); and Regional Innovation Systems (RIS). Therefore, the IS approach has been applied at national (Freeman, 1988; Nelson, 1988; Freeman, 1995; Lundvall et al., 2002), regional (Cooke & Uranga, 1997; Cooke, 2001), sectoral (Malerba, 2002; Oltra & Maider, 2009) and technological (Bergek et al., 2008) levels.

The core idea behind IS approaches is that change, especially technological one, can be ascribed to both collective and individual actions relating to innovation systems (Freeman, 1988). The main focus is to break down system into its constituents to discover which system elements do not fulfil their intended purpose, thereby hampering the development of the entire system (Jacobsson & Bergek, 2010). Innovation system theory allows analysing the success or failure of a technology on the basis of the performance of the surrounding technological system (Carlsson & Stankiewicz, 1991). In general, analysis includes identifying the key structural elements (e.g. actors, institutions, interactions and infrastructures) and key functions of an IS (Twomey & Gaziulusoy, 2014). As for the structure of IS, a classificatory system was developed by Wieczorek & Hekkert (2011) based on four key structural dimensions: actors (public, private, civil society), institutions (soft and hard), interactions (networks, individual contacts) and infrastructure (physical, knowledge, financial). More recently, attention has turned to the dynamics of innovation and the so-called functions of innovation systems. The main purpose of this approach is to consider all the activities that contribute to the development, diffusion, and use of innovations as system functions (Hekkert et al., 2007; Bergek et al., 2008): entrepreneurial activities, knowledge development, knowledge diffusion/knowledge exchange, guidance of the search, market formation, resource mobilisation, support from advocacy coalitions.

The concept of agricultural innovation system (AIS) is strongly linked to that of agricultural innovation. The Agricultural Knowledge and Information System (AKIS), whose main functions are to foster mutual learning and to encourage knowledge sharing and utilization (FAO, 2000), emerged in the same period as AIS (Table 3). Agriculture innovation system concept emerged in the late 1980s, but it has tremendously evolved since then. It emerged in response to shortcomings of linear transfer of technology frameworks (Röling, 2009). AIS builds on other strands of agricultural development literature such as participatory frameworks (Chambers, 2005; Hall, 2007) and farming systems research (Collinson, 2000; Darnhofer et al., 2012). It draws attention to individuals and organizations capacity to make knowledge (especially scientific knowledge) useful in agriculture (Spielman et al., 2009) as well as how complex interactions between public, private, and civil society actors influence agricultural develpment (Ekboir, 2003; Spielman et al., 2009; Basu & Leeuwis, 2012). AIS draws also attention to the fact that multiple subsystems within agriculture (e.g. education and training, farmers and their groups, extension, research, public institutions, donors) are relevant in agricultural innovation (World Bank, 2012). It argues that new technologies areinsufficient to assure agricultural development; focus on whole innovation process is needed (Hall et al., 2010). In AIS, innovations can emerge from different actors such as farmers and other local actors (Spielman et al., 2011) using different types of knowledge (Biggs, 2007. It also highlights the importance of collaborative networks as well as 'Innovation platforms' in driving innovations (Ekboir, 2012; Hounkonnou et al., 2012). Collaboration with institutional structures, ensuring involvement of actors across institutional settings, and understanding of institutional contexts significantly influence technical innovations effectiveness (Clark, 2002). AIS approach also emphasises that capacity building, both individual and organisational, lies at the heart of innovation (Mbabu & Hall, 2012).

Current agricultural innovation systems (AISs) are characterized by two main factors: combination of private, civil society and academic

participants (farmers and their organisations, inputs and services providers, research and support organizations, extension and advisory services, etc.) involved in creating, disseminating, adapting and using knowledge, and dynamic interactions among these participants (World Bank, 2006; OECD, 2013; IIAC, 2014). Both, innovation platforms and innovation networks, have inherent tensions and complexities (Foran et al., 2014). Therefore, AISs are increasingly recognized as complex adaptive systems in which a wide array of actors – from research, extension, business and policy domains – adapt their actions and strategies based on the actions of others as well as changing system conditions (Spielman et al., 2009; Klerkx et al., 2010). Conversely, actors' actions induce changes in the structure and functioning of the AIS and determine innovation adoption speed and pathways (Douthwaite & Hoffecker, 2017). According to Turner et al. (2017), elements for triggering system innovation within AIS include: supporting reflexivity to challenge underlying institutional logics related to systemic problems; including a heterogeneous group of actors from multiple sectors (farmers, research organizations, government, etc.); encouraging an iterative and flexible process of practical experimentation that supports systemic changes and challenges current practices; and promoting generative collaboration.

The IS approach is attractive for policy makers since it pinpoints bottlenecks in system innovation and transition processes (Smith et al., 2010; van den Bergh et al., 2011) and has become one of the strands of transitions research (Alkemade et al., 2011). However, the IS approach has not been without criticism (Hekkert et al., 2007; Smith et al., 2010; Geels 2006, 2011; Lachman, 2013): it focuses more on system functioning/failure rather than system change, pays low attention to reasons behind system weaknesses and gives little attention to system dynamics.

The modern innovation theory provides a number of concepts and insights similar to that of transition (Twomey & Gaziulusoy, 2014; Tyfield, 2011). The common term 'transition' is often used interchangeably with the term 'systems innovation' (Kemp & Rotmans, 2005). In the 1990s, the 'transition' concept was introduced within socio–technical research (Lachman, 2013). In the latter, 'transitions' initially referred to large-scale transformations within society or important subsystems (Rotmans et al., 2001). More recently, Loorbach & Rotmans (2010) defined transition as "a fundamental change in structure (e.g. organizations, institutions), culture (e.g. norms, behavior) and practices (e.g. routines, skills)". According to Sterrenberg et al. (2013), radical systems innovations or transitions involve "innovations that are directed to redesigning entire systems of practices and provisions, instead of individual products or processes".

There have been efforts towards integrating innovation systems approach and the socio-technical transitions approach as these perspectives have developed to some extent independently and there has been cross-fertilisation of ideas (Markard & Truffer, 2008; Meelen & Farla, 2013). Similarly, although innovation systems and sustainability transitions research fields have had different evolving paths, they began to merge in recent years (e.g. Sustainability Transitions Research Network [STRN], 2010, 2017). Furthermore, both fields have proven important in the debate on sustainable innovation.

The socio-technical transition approach (Kemp, 1994; Geels, 2005; Rotmans et al., 2000) is an umbrella term that includes the Multi-Level Perspective (MLP) and multi-phase model, Transition Management (TM) and Strategic Niche Management (SNM). The last two approaches emerged partly from MLP and have a more normative and governance orientated focus for supporting radical innovations and system transformations. The MLP approach differs in focus and scope from the IS approach. The MLP research emerged partly from historical studies of system changes and evolutionary economics. Moreover, MLP is conceived in a societal context that is broader than the innovation systems approach. The first version was introduced by Rip and Kemp (1998) and was refined and developed in the 2000s by the empirical research of Frank Geels (2005). A central theme is the recognition of the co-evolutionary development of technologies, institutions and social

and economic subsystems. MLP is particularly powerful in understanding the complex interplay of different forces at the macro-, meso- and micro-level in creating disruptive change. It posits three levels to aid understanding transitions: a landscape (macro) level that encompasses the dynamics of deep cultural, economic and political patterns; a regime (meso) level that refers to the current practices, routines and dominant rules that prevail in a socio-technical system; and a niche (micro) level that represents the space where actors experiment with radical innovations that may challenge and break through into the prevailing regime (Geels, 2010; Geels, 2011). In transition studies dealing with food systems (e.g. El Bilali & Probst, 2017), regimes can refer to business regulations and codes, food safety law, existing transport and logistics infrastructure, or business networks (Hinrichs, 2014). Niche innovations include organic agriculture (e.g. Smith, 2006) and alternative food networks that shorten supply chains (e.g. Goodman et al., 2012; Kirwan et al., 2013). MLP is the most prominent heuristic framework in sustainability transitions research.

The momentum generated by the diffusion of the term 'sustainable development' spurred interest in research on 'sustainability transitions' (Markard et al., 2012; Lachman, 2013; Falcone, 2014). The notion of 'sustainability transition' was coined to embracing the goal of transition towards sustainable systems (Geels, 2011; Kemp & van Lente, 2011; Lachman, 2013). Markard et al. (2012) defined sustainability transitions as "long-term, multi-dimensional and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption". Sustainability transitions are needed to move towards sustainable food systems. IPES-Food (2015) pointed out that a multi-directional flow of knowledge between the worlds of science, policy and practice is needed to foster a genuine transformation of food systems, which is necessary to make transition towards sustainability. Transition will most likely not depend on one or even a small number of technological innovations, but is likely to arise from a constellation of mutually interacting systems of innovations (Twomey & Gaziulusoy, 2014). This is particularly true in the case of food system where social innovations seem also important. In fact, social and organizational innovations are as central to sustainability transitions in food systems as any particular innovative technology (Hinrichs, 2014; Darnhofer, 2015; IPES-Food, 2015).

CONCLUSIONS

The literature on innovation and transitions is enormous, but this review focused only on key concepts and frameworks that are relevant for the agro-food sector. Innovation is widely recognised as a critical dimension of sustainable consumption and production, sustainable food systems included. However, many questions have been raised on the ability of the current innovation model to meet food security and nutrition of future generations in a sustainable way.

There are several variations in the use of the term 'innovation' that depend on the novelty of knowledge used in the innovation, where the innovation is located in the value chain, or the extent of innovation impact. Technical innovations are widely advocated for a sustainable intensification of food production, while social innovations seem more relevant in consumption stage of the food chain. In the last decades, there has been a shift from an innovation concept centred on research to innovation as a result of interactions among several actors that establish diverse networks and linkages in an innovation system. Furthermore, recognition of the complexity of systemic innovation or transition favoured the emergence of some heuristics such as the Multi-Level Perspective (MLP) on transitions.

Recently, the scope of innovation in the agro-food sector was broadened with a particular focus on innovation impacts in terms of sustainability that's to say contribution of innovation to agro-food sustainability transitions. This is shown by the growing emphasis on the concept of 'sustainable' innovation also in the agro-food arena. Moving towards 'sustainable' or 'sustainability-oriented' innovation seems to be

a step in the right direction to overcome resistance to change in the agro-food arena thus making smoother transition towards sustainable food systems. Future agro-food innovation needs to address not only simple technological and technical issues, but also social ones and to innovate in scales of thinking and action in order to contribute more effectively in addressing pressing challenges such as climate change and food insecurity.

Conflict of interest

Author has no conflict of interest to declare.

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