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Acceptance of Innovation and Pathways to Transition Towards More Sustainable Food Systems

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Abstract The main driver of agricultural systems of the twentieth century was yield. Awareness of the limits of the planet and the impacts of agriculture triggered the realization that new objectives have to be part of the food systems agenda. The development of new models of agriculture including environmental and sustainability dimensions implies a new view on the process of innovation and a better balance between the paradigms of innovation. Systemic lock-ins are keeping the agricultural and food systems on less relevant pathways. Acknowledgement of the relevance of alternative systems of production such as organic farming and a shift from a linear model of innovation diffusion to the building up of new partnerships of innovation are key enablers of a transition.

Keywords Food systems sustainability · Innovation paradigms · Transition pathways

From Adoption to Innovation

The process of innovation is commonly seen as based on a linear sequence: innovative techniques are developed in research centres and then disseminated to farmers and other actors in the field. An adoption process is taking place (Rogers 1995). The impacts of innovation for farmers and society are assumed to depend on the level of adoption. This view assumes a direct link between the developer of the innovation and the farmer. It also assumes that all farmers' choices are made rationally and without influence.

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In the reality of the agricultural sector such as the potato value chain, the situation is more complex because many actors are involved. Industries related to the development of inputs (pesticides, herbicides, fertilizers, machinery) and public and private consulting services are main actors of the upstream of the value chain. Downstream, farmers' decisions are influenced by processors and distributors, by public policies, by consumers and by citizens. In such a multi-actor environment, pathways of innovation are more an emergent systemic process than the consequence of a choice made by the farmer alone.

Since the end of the twentieth century, the overall framework of agriculture has evolved. In the twentieth century, the main expectation of society vis-à-vis agriculture was the production of abundant and cheap food. The technical choices at the plot and farm level focused on increasing and maintaining yields. Varietal choices and technical choices were aligned with this goal. In the late twentieth century, awareness of planetary boundaries and assessment of the impact of the industrial and agricultural model on the environment have led to new goals (Tilman et al. 2002). Without denying the need for a high productivity, it became necessary to integrate other dimensions: sustainability, quality and diversity of products, health impacts. These new dimensions were first driven by societal demand and even, often, by pressure groups. They have gradually generated new expectations about food systems and therefore about agricultural production (De Schutter and Vanloqueren 2011). The challenge today is to meet these expectations in an agricultural system that is locked into productivity goals. This challenge is all the greater as the corrections to be made to the current system are important (Foley et al. 2011). Responding to this new situation implies a new vision of innovation as a multi-stakeholder process in which trajectories can be diverse.

We will take two examples to highlight these new processes: (1) the balance between the genetic characteristics related to productivity and sustainability, and (2) the consideration of the diversity of modes of production within a sector and potential imbalances between these different modes of production.

Genetics: a New Balance Between Different Traits

Yield was the main driver of genetic improvement in the twentieth century. The goal was both to meet societal expectations regarding food production and to provide income to the farmer. Most of the research articles, commercial communication and extension pamphlets focused on a single output: yield. The productive performance was also a key element of social recognition among farmers (McGuire et al. 2013).

Considering the new constraints assigned to food systems, geneticists are asked to maintain this level of yield while integrating other breeding objectives: disease resistance, reduction of fertiliser use, drought resistance and technological and taste qualities. Two strategies are possible: either integrate these new characteristics into existing varieties or develop new varieties based on these new expectations.

In a study on the control of late blight in Belgium, we highlighted the importance of varietal choice in susceptibility to late blight. In Belgium, the main varieties were chosen according to technological characteristics and productivity performances. Little attention has been paid to resistance to late blight and, as a result, the main varieties require regular use of phytosanitary products to control late blight. This choice in favour of productivity without a significant attention to sustainability issues was built progressively and in good agreement with a variety of actors. This combination of norms and practices shared between actors of a system is described by the concept of the socio-technical system (Fig. 1) (Geels 2004).

These socio-technical systems have the property of creating their own coherence and are therefore resistant to radical changes. To evolve these systems towards new objectives implies the identification of the different lock-ins to the change. In a study of fungal disease management in wheat, we identified 12 different lock-in factors favouring the maintenance of a system based on the use of pesticides (Table 1) (Vanloqueren and Baret 2008). Various studies confirm this multi-factorial nature of lock-ins (Cowan and Gunby 1996; Meynard et al. 2013). Jointly addressing this galaxy of lock-ins is one of the keys to moving towards new practices and systems. The other option is to develop alternative systems that are then likely to interact with the current dominant system. These alternative systems can be built de novo or can be identified among the diversity of current production systems.

Diversity of Production Systems

An alternative way to address the necessary transition of food systems is to favour production systems that are in line with the new expectations and to disinvest the less relevant pathways.

For example, the new environmental expectations of citizens and consumers are addressed by the trajectories of production systems such as organic farming. Organic farming is based on a certification principle (Darnhofer et al. 2010). The choice to exclude certain technologies and uses has led to the development of new approaches to innovation based on two dimensions: (1) the use of alternative innovation paradigms and (2) the construction of new partnerships. Dosi (1982) distinguished between two dimensions in innovation processes: the paradigm of innovation and the trajectory of innovation. The innovation paradigm is the knowledge stock from which we can draw solutions to build an innovation trajectory. We can distinguish different paradigms: a paradigm favouring solutions based on synthetic chemistry, paradigm favouring

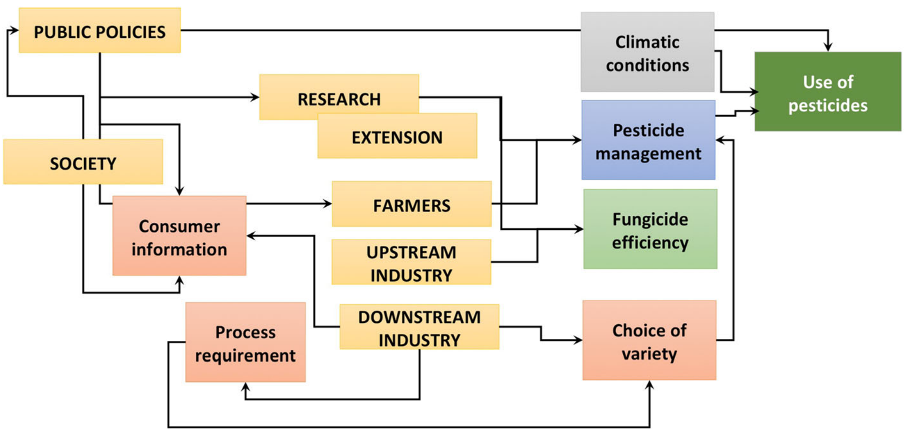

Fig. 1 The socio-technical system in the Belgian potato sector

Table 1 Factors determining lock-ins on a pesticide-based innovation pathway (Vanloqueren and Baret 2008)

Farmers	1·Direct cultivar choice criteria of farmers: disease resistance comes only after gross yield, resistance to lodging and commercial quality
	2·Incomplete resistance of resistant cultivars and the unpredictability of epidemic development
	3·Limited number of cultivars resistant to all frequent diseases
Market	4·Contradictory objectives of crop protection and seed departments in supply companies (which disadvantages resistant cultivars)
	5·Influence of supply companies' sales people on farmers' practices
	6·Breeding history and breeding objectives of seed companies
Public extension services and research	7·Omnipresence of gross yield and absence of economic optimum estimates
	8·Concentration on one cultural system at the expense of alternative systems
	9·Perception of, and information given about, resistant cultivars
Public regulation	10·Cultivar registration norms
	11·More important challenges: food safety, traceability, etc.
Past agricultural policies	12·Payments based on output influenced cultivar choice towards highest-yielding cultivars

approaches based on genetics and paradigm inspired by ecosystem services. These knowledge/solution stocks are sometimes overlapping, but the different clusters of solutions are built on different rationale.

When a system of actors faces a problem, it will favour an innovation paradigm based on the training of actors, their worldview and their evaluation of the effectiveness of the proposed technologies. As stated by Dosi (1982), a technological trajectory is the "pattern of normal problem-solving activity (i.e. of progress) on the ground of a technological paradigm". The pattern of progress of a given pathway is highly dependent on a given paradigm of innovation.

In an ideal world with infinite resources, investment in the different pathways would be equivalent and different stocks of knowledge would be equally available and offer the actors a diversity of complementary propositions.

The observation of the actual functioning of the innovation systems in place today contradicts this hypothesis. Innovation systems are in competition, and a strong imbalance exists between paradigms of innovation. Resources are limited, and a minority of systems capture a majority of resources (Vanloqueren and Baret 2009).

Similarly, at the level of trajectories, the actor should choose the best possible solution to his or her problem regardless of the origin of the innovation. In practice, cognitive and cultural dimensions, the balances of power and influence determine the choice of the actor. Actors of a given production system most often resort to the same paradigm of innovation. The industrial sector will rely on mechanization, classical or molecular genetics and solutions based on synthetic chemistry, while the organic sector will favour an agroecological paradigm, inspired by the functioning of natural ecosystems.

Another difference between the different production systems is the organization of the diffusion of innovations. The most traditional production systems operate with a relatively linear innovation chain. Research centres build solutions based on stakeholder requests and driven by advances in basic research. The technical solutions are then assessed and disseminated by organizations of applied research and extension. Farmers adopt these innovations based on their own analysis but also by different forms of communication, neutral (extension service) but also oriented (advertising).

In alternative systems such as organic farming, the construction and diffusion of innovation relies more on networks and partnerships (Morgan and Murdoch 2000). In addition to the role of research institutes, a real place is given to local knowledge and field actors. The co-construction of innovation between actors facilitates the adoption phase. Indeed, from the beginning of the process, the actors have been associated with the different options. Consequently, the innovation is built into their systems and not externally proposed.

While many authors agree on the urgency of a transition of agricultural and food systems given the rapid degradation of environmental indicators, imbalances persist between innovation models and the most potentially relevant solutions remain largely under-invested. This difficulty to change can be explained by a Matthew effect in science (Merton 1968). The actors who are most recognized in a given system and who have been effective in the past are those who capture the majority of the media aura and financial and human resources even if the solutions they propose have little long-term relevance.

Facing the challenge of the twenty-first century implies a delicate balance between respect for the diversity of production, processing, distribution and consumption systems and a necessary strategic commitment around the most relevant options for the future challenges.

On the one hand, the agricultural milieu is agitated by tensions between the supporters of the different models. On the other hand, a disagreement is growing between the society, and particularly civil society, and the main actors (farmers, unions, private companies etc.) of the agricultural sector.

These tensions are determined by a series of misunderstandings. Firstly, a better understanding of the mechanisms and pace of innovation in agriculture would allow for a more balanced investment in a diversity of innovation paradigms. Secondly, new channels of communication between society and farmers, in all their respective diversities, are required (see for example the OSAE experience in France - OSez l'Agro Écologie). Thirdly, the focus should move from farmers to the whole value chain. Indeed, farmers' leeway is limited, especially in the more integrated systems such as the potato system. Fourthly, more emphasis should be put on the socio-economical shortfalls of some agroecological models regarding working conditions (Dumont and Baret 2017).

Conclusion

The transition towards sustainable pathways is impossible if lockouts are maintained and growing. Conversely, this integration can be effective if new strategies are considered. The farming systems of the twenty-first century are evolving in a new context. Taking into account this context implies a new relationship with society to understand both the expectations of citizens and the specificities of the agricultural world (Hervieu 2001).

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