Obstacles to the diffusion of innovation in the agricultural sector

Wolfgang Bokelmann, Bettina König[1]

1. Innovation: the key to meeting future challenges

To meet the needs of the world's rising population, food production must increase significantly. Because resources are scarce and soils are being progressively degraded, production must happen in a way that preserves available resources for use by future generations. Development of the agricultural system, however, needs to take into account changing geophysical and socio-economic conditions. The consequences of climate change require major adjustments in agricultural production. Furthermore, increasing urbanisation in nearly all parts of the world requires well-organised food systems supplying urban populations with sufficient healthy food. In industrialised countries, the consequences of resource-intensive agriculture are increasingly visible. Following a number of food scandals, consumers consider our current form of agriculture to be a critical issue.

While the direction of innovation in agriculture has its critics, there is little doubt in society that the food sector needs innovation. International competition, globalisation, changes in the environment and the changing demands of consumers and society are all factors in the need for innovation to ensure a sustainable and healthy food supply for a growing population and success in the market. (European Commission, Directorate-General for Research and Innovation, 2015; Garnett and Godfray, 2012; Godfrey *et al.*, 2010, Ingram *et al.*, 2013; Wunder and Bausch, 2014).

2. Driving forces of innovation

Current production, processing and marketing practices were once novel and innovative. There are a range of drivers of innovation and factors that affect the magnitude and direction of various innovations (see Figure 5.1). In the seventies, most changes were associated with increased competition associated with the opening of markets. The retail industry, processing industry and agricultural production reacted to this challenge by improving efficiency and productivity along with strong company expansion. As wages rose, labour-saving investments were made. The focus was on increasing of productivity, achieving "economies of scale" and "rationalisation", all of which aimed to reduce production and logistics costs. These developments are sometimes known as the "agro-industrial model" (Fournier/Champredone 2014).

[1] Bettina König, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany

Figure 5.1. Driving forces of innovation in the agricultural sector.

With the gradual emergence more anonymous global value chains, the issues of food health and safety have entered public awareness. Food scandals in particular have shone a spotlight on the issue of food safety. There have been various initiatives in both at the state and the private sector levels to reduce consumer health risks. Organisational innovations such as certifications and process standards have increasingly been implemented. The market has grown considerably due to an expanding market supply and greater efforts to differentiate products. This development was also a result of strong consumer demand as incomes and income inequalities intensified sharply over time. All these trends have offered opportunities for product differentiation and processes, including organic products, local food, or producer and private label brands. Generally speaking, branding has played a role even in agriculture.

The current discussion on animal welfare and climate change reflects particular societal demands and the way food is produced, processed and marketed, resulting in specific marketing requirements. The marketing opportunities these trends offer can only be effectively exploited if trust is built among consumers. Because consumers are unable to verify whether such claims as "environmentally friendly" or "fair trade" are true, labels and certifications are a way for brands to be perceived as trustworthy by consumers.

These developments all exemplify very different driving forces of innovation. However, they also show that the concept of innovation is not restricted to new products. Product changes are often associated with process and social innovations, which will be discussed in further detail below.

3. Delving into the concept of innovation

In everyday use, the term "innovation" is applied to almost anything that appears to be new. This universal use makes scientific communication on the subject quite difficult. It is especially

challenging to make general recommendations regarding the design of innovation processes. We must therefore come to a consensus on the use of the term and distinguish it from other similar terms.

Generally speaking, innovations are new solutions that have already been proven usefulness in practice. This means they have successfully passed different phases, from development to acceptance by the user: decisions to develop and introduce inventions onto the market, as well as the adoption of such inventions by users, have already been taken. From this perspective, it should be stressed that in addition to product innovations, process and social innovations are increasingly necessary. If we look to value chains, we will find that many innovations are aimed at improving processes within companies as well as cooperation between companies, thereby making the entire process more efficient. For social innovations, certifications by non-governmental organisations are often required to gain the necessary acceptance of new or modified products.

Innovation also differs in whether it leads to incremental or radical changes (Figure 5.2), i.e., "new to the world". New plant varieties and pesticides would be an example of an incremental innovation: they do not require users to acquire much additional knowledge to be able to use them. New technologies, on the other hand, such as for precision farming or lighting for horticultural plants, are relatively radical changes and require a considerable amount of new knowledge for use. In addition to distinguishing between incremental and radical innovation, we can also look at whether changes are only needed for a subsystem or if far-reaching changes across the company as a whole are required. If production processes must undergo fundamental changes, how much and what type of new knowledge is needed and whether employees will need new qualifications are also factors that can be taken into account. Upon closer examination, many innovations are shown to be more systemic in nature. Incremental changes and narrowly focused innovations affecting only certain areas of a company's business need little support to implement and have a lower economic risk. The private sector generally manages this type of change very successfully.

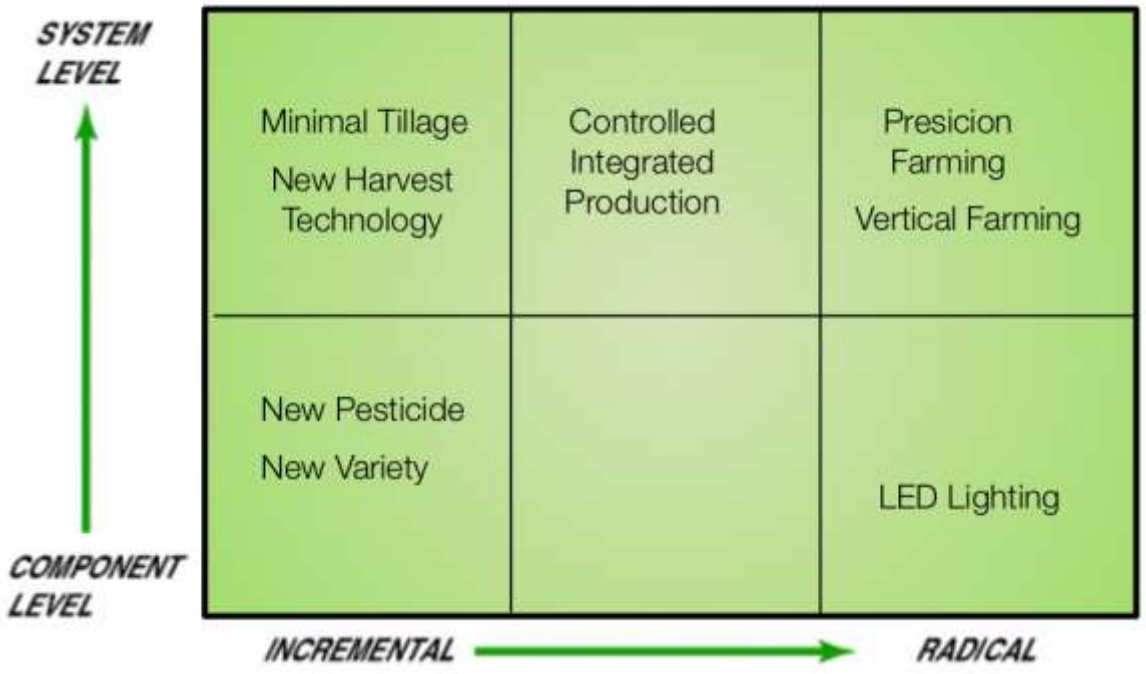

Figure 5.2. Types of innovations (changed according to Tidd/Bessant 2009).

For radical changes on a system level, several technology components are combined to create value.

This type of innovation requires a complex innovation network, which must often take an interdisciplinary approach. Rather than the level of innovation of individual components, the key to this system is their new combination. Larbig *et al*. (2012) considered that the generation of profound changes was a basic feature of system innovations: (1) they are inspired from the real world, e.g. social and environmental problems, and include a multidimensional degree of novelty, (2) they change market and stakeholder relations as well as existing knowledge, technologies and/or organisational forms, and (3) they need a strong customer focus as a driver. The viewpoint is based on a need (market pull). In the event of a comprehensive set of complex changes, e.g., in production or operational procedures, there is a greater need for knowledge and training for the whole innovation process. Additionally, acceptance by the company or customer is difficult to predict. Such innovations are associated with significantly higher economic risks. During the process, a large number of actors on different levels are involved or affected (see also Geels, 2005). When it comes to global challenges or meeting societal needs in a better way, system innovations play an important role.

System innovations require skills outside their core competencies and are often developed within inter-organisational networks. Sharing knowledge and joint influence within networks is important and can help limit risks.

4. Practical experience

Through various projects, we have dealt with the development and adoption of innovations in the agricultural and horticultural sector (Bokelmann *et al.*, 2012; König *et al.*, 2012). To get a complete picture, we worked through various case studies using a mixed method approach. In addition to the analysis of secondary statistical data and qualitative and quantitative surveys, we have conducted workshops with various value chain stakeholders in these fields. This is necessary because often all players in the value chain must accept the innovations. The following section summarises several experiences from our studies. The aim is to highlight the obstacles to the development and adoption of innovations and offer recommendations for overcoming those obstacles.

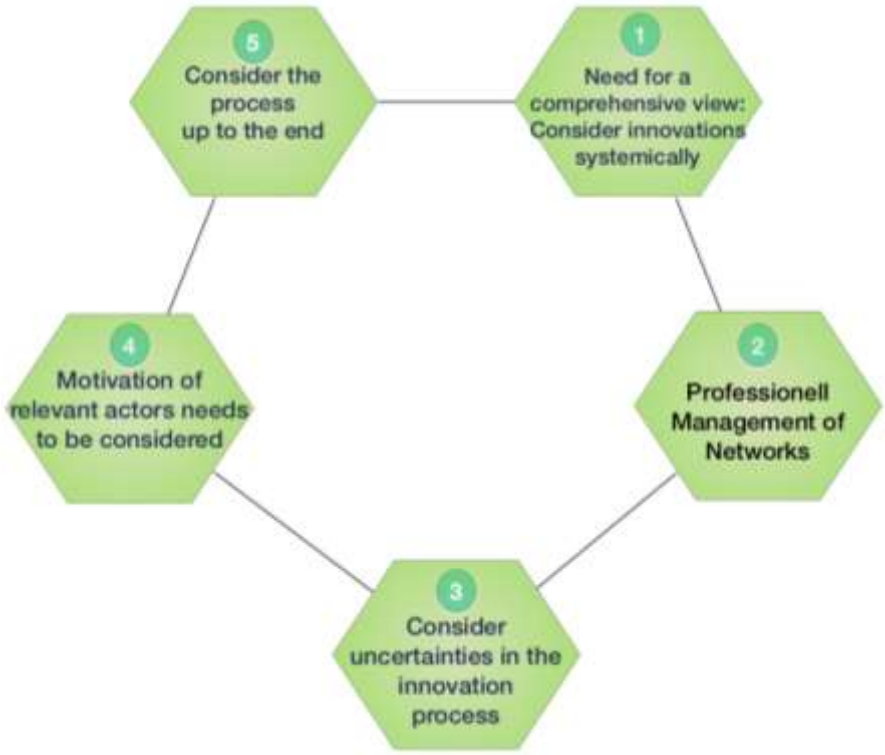

Figure 5.3. Success factors for systemic innovations.

5. Taking a systemic view

Given the background information previously given about systemic innovations, the actors involved in such processes and who are part of the innovation system must be considered. As already discussed, there are different framework conditions, organisations and individuals to support the adoption of innovations. The way these organisations and individuals interact determines how successful the innovation process will be. In agriculture especially, a wide range of mainly small-scale businesses is prevalent, and even the supplier industry is still dominated by small- and medium-sized enterprises (although there is a strong concentration process in the field of breeding and the production and distribution of fertilisers and pesticides). When it comes to societal demands (reducing greenhouse gases), pure market solutions often have limited success. As such, innovation also requires input from public research and development institutions.

Analysis should also take into account that agriculture today is part of value chains that can be very complex and that many new features of discoveries are based on technologies invented outside the agricultural sector. Experimental stations and demonstration farms where the practical use of such innovations can be proven are necessary. Moreover, actors who can support (broker) the adoption of innovations need to be involved, such as the media, education system and training institutions that are active in the sector (Klerkx/Leeuwis, 2009). Furthermore, educational stakeholders are just as important as independent consultants.

To capture all these actors and their interactions systematically, we used the sector-innovation model by Malerba (2002) in our studies (Figure 5.3). It shows the driving forces of innovation, such as intensified competition, as well as new technologies that have been developed and, even more important today, the changed demand structure (Edler 2016; Rubik/Müller 2016; Raisch 2003). The actors and their interactions are shown with a special focus on the knowledge base or existing human capital. The system rules ensure that institutions and policies are able to play a role. In our

study the Malerba model was extended so that the various phases of the innovation process were itemised separately. It is clear that the importance of the different actors during innovation process can change substantially.

Figure 5.4. The sectoral system of innovation (changed according to Malerba 2002).

5.1. Innovation networks

The vast number of companies participating in the group discussions showed that the role of networks in the innovation process is very important. Networks can pool resources of the actors involved and promote the rapid dissemination of information within the group to initiate and promote learning processes (Weyer 2011). However, there is often little information on existing networks and potential partners are not always known, such as when basic technologies for innovations are developed outside the agricultural sector. However, all the functions can only be fulfilled when such networks are professionally managed. To this end, sufficient financial resources must be made available.

6. Uncertainty in the innovation process

A second important factor is uncertainty in the innovation process. Uncertainly plays an essential role in research and development as well as in the adoption of innovations by agricultural companies. The majority of players in the sector, including suppliers, are small- to medium-sized enterprises that do not have extensive research capabilities or staff planning. Innovations are also dependent on other actors in the value chain being willing to accept them.

For adoption itself, it is important that innovations have already been shown to be useful. This can take place through demonstration projects as well as by leading companies in the sector using the technology and sharing their experience. In principle, reliable information (e.g., from independent consultants) is of the utmost importance. In individual cases, especially combined with societal

demands, government subsidies are helpful for reducing uncertainty and guiding how to put new technology into place.

7. Incentives in the innovation process

A more thorough analysis of essential activities of innovation networks shows that a precondition for the success of innovations is for actors to be motivated to cooperate. In this respect, it is also important to consider the incentives of actors more precisely. For example, there little interest for scientists to actively engage in innovation networks when their home institutions are more focused on high-ranked scientific publications than on practical research and writing for business magazines. For farmers, social challenges such as climate change are seen as relevant but remain relatively abstract. For them, it is important that the economic benefits of the adoption are clearly shown.

In Germany, the role of the advisory system has changed significantly in recent years. Previously the focus was on independent advice while today the fulfilment of sovereign tasks is increasingly important. It should be noted, however, that there is a certain contradiction between control functions and independent advice.

8. Considering the entire process

Policymakers are often asked to set clear and reliable targets that allow for long-term investments in new technologies and products. Often, a special focus of innovation policy lies in funding research and development. To successfully launch an invention, additional obstacles must be considered, especially those related to the adoption phase. New technologies and new process innovations require improved knowledge and as such, appropriate levels of education and training must be included. Additionally, the integration of the so-called lead users in the entire process is increasingly recognised in innovation research. They can contribute to the development process and have direct contact with farmers to demonstrate the advantages of innovations. A similar function is expected from practical experimental stations. To reduce uncertainty and convince farmers to adopt innovations, they must have successfully demonstrated economic or social benefits.

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