Agricultural Systems 138 (2015) 55–65

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Analysis of animal monitoring technologies in Germany from an innovation system perspective

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ARTICLE INFO

Article history:
Received 17 June 2014
Received in revised form 13 May 2015
Accepted 25 May 2015
Available online 18 June 2015

Keywords:
Animal monitoring
Precision livestock farming
Sectoral innovation system
Innovation processes
Systemic intervention
Governance

ABSTRACT

In order to address societal demands (e.g., animal welfare, traceability, environmental aspects), animal monitoring (AM) technologies provide much potential for innovation in animal production. AM means the real time and on-going automatic monitoring by 'smart' sensors of physiological, growth and behaviour parameters of individual farming animals, integrated in various areas (e.g., animal milking, feeding, breeding, health). The literature on AM mainly focusses on technologies and their application. The available information about innovation processes in AM is still very fragmentary and not comprehensive. The present article analyses the generation, development and use of AM technologies in Germany from a dynamic innovation system perspective. The analytical framework of the article is based on the sectoral innovation system approach. Qualitative interviews, an expert workshop, and a Delphi survey were conducted to explore the roles and interactions of heterogeneous actors in innovation processes and the interlocking between innovation stages. On the basis of identified fostering and inhibiting factors, opportunities for systemic interventions are suggested to further innovations in AM and in the German animal production sector and in other countries. These interventions consider, on the one hand, recommendations to support AM technologies and their broader implementation ('hard skill interventions') and, on the other hand, interventions that are suitable to stimulate innovations in animal production without specific focus on a single technological regime or innovation area ('soft skill interventions'). The 'hard skill interventions' refer to the need for improvements concerning system compatibility and data exchange; the special need for financial support of extensive validation of AM technologies and clear communication of benefits or constraints to farmers. 'Soft skill interventions' are related to innovation capacity building of actors in order to coordinate co-development processes and to improve communication: Finding of a common understanding of the innovation system and common language among actors; early involvement of all actors and the reflection of actors' roles; resource-based fostering of network management. Finally, innovation policies should be capable to gather and react appropriately to these requirements. Generally, the study contributes to a better understanding of the complexity of innovation activities in AM and their embedding in the innovation system of animal production. The opportunities for systemic intervention can be used by the sector's actors to enhance the innovativeness of the German sector and to make better use of AM potentials to address the global challenges and societal demands.

1. Introduction

Globally, the animal production sector is facing current and future challenges, such as increasing societal and consumer demands regarding animal welfare, food safety and traceability of food origin, health issues, and environmental sustainability (Berckmans, 2006, 2008; Bracke et al., 2005; Petersen et al., 2002). To remain competitive in markets, animal producers and processors must address these challenges by successfully establishing innovations in markets (European Commission, 2012; Meynard and Casabianca, 2011).

Due to the complexity of tasks (e.g., advanced health monitoring, traceability along the value chain) associated with these recent challenges and growing herd sizes, farmers' analogue visual monitoring of individual animals through observation is increasingly insufficient (Berckmans, 2006). Thus, information and sensor technologies, implemented through animal monitoring (AM) technologies, have generated substantial potential for innovation in animal production (Banhazi et al., 2012; Banhazi and Black, 2009; Berckmans, 2008). Studies have discussed the ways in which AM technologies can contribute to

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http://dx.doi.org/10.1016/j.agsy.2015.05.009
0308-521X/

addressing the abovementioned societal and consumer demands: e.g., pig husbandry systems to ensure animal welfare and sustainability considerations (e.g., Elzen et al., 2011), perceptions of animal welfare obtained through different types of monitoring (Bracke et al., 2005), food safety and traceability supported by RFID (Ruiz-Garcia and Lunadei, 2011) or computerised health management in pig husbandry (Petersen et al., 2002).

AM involves the use of 'smart' sensors to automatically monitor various livestock parameters, such as animal physiology, growth and behaviour (Wathes et al., 2008). AM is generally conducted at the individual animal level, meaning conducting real-time and on-going variable measurement when the animal is in the herd (Berckmans, 2008). It encompasses technologies from various areas (animal husbandry, feeding, animal health and milking) and different production lines, such as cattle, hog or poultry production. AM technologies are implemented either as stand-alone solutions or integrated components of more complex systems (e.g., active sensor systems). The collected monitoring data are used in decision making concerning complex production processes and accordingly integrated into sensor-data based (herd) management systems, or so-called precision livestock farming (PLF) (Banhazi and Black, 2009; Berckmans, 2006, 2008).

The evolution of AM technologies can be divided in various generational stages, from simple forms of animal identification via RFID in the 1970s to the recent third generation of enhanced and complex systems (Eradus and Jansen, 1999). In addition to such descriptions of the historical evolution of the technologies (see also Ordolff, 2001), many researchers focus on specific AM technologies: their technological development, application, functionality, practical experience or recommendations (e.g., Eigenberg et al., 2008; Pastell et al., 2008; Pereira and Nääs, 2008; Chesmore et al., 2003; Scheibe et al., 2003; Petersen et al., 2002).

Nonetheless, the successful development of AM technologies and their broad implementation on livestock farms and in markets to address the sector's challenges do not solely rely on the technologies per se. These innovation processes are accompanied by organisational, institutional and technical changes and are embedded in the complex structures of the innovation system in animal production (cf. Klerkx et al., 2012; Knickel et al., 2009, 74; Leeuwis, 2004). The innovation system constitutes the framework that defines how actors and institutions collaborate and exchange knowledge to create and diffuse innovations. Hall et al. (2003) provide the following definition: 'A system of innovation involves all the actors and their interactions involved in the production, use of knowledge, and the institutional and policy context that shapes the processes of interacting, knowledge sharing and learning.' Only by understanding this system and the functioning of innovation processes can the systemic preconditions for the success or failure of innovations be discovered (Hall et al., 2003; Carlsson et al., 2002). Thus, knowledge and insights concerning these framework conditions and system components, the system's actors and the interplay among them, market conditions and demand, the knowledge base and infrastructure and legal regulations are necessary (Hall et al., 2003). Currently, such systemic perspectives on innovation processes have gained predominance in agriculture and the animal production sector (Klerkx et al., 2012; SCAR, 2012; Dockès et al., 2011; Knickel et al., 2009; van Dijk and van Boekel, 2001).

Since the beginning of the discussion on the role of innovations and their development, different perspectives have emerged. Linear innovation models were long the predominant approach in agriculture and other sectors (Klerkx et al., 2012; van Dijk and van Boekel, 2001). Such linear perspectives are suggested by Roger's 'diffusion of innovations' (2003, first published in 1962) or Ruttan and Hayami's (1984) 'induced institutional innovations'. In recent decades, many researchers abandoned this linearity concept, following the understanding that innovation processes in reality are far more complex. Innovation processes include various feedback loops between the development stages and rely on different sources and impulses, not exclusively science (Kline and Rosenberg, 1986). Such observations formed the foundation of more systemic perspectives on innovation in the 1990s. In the animal production sector, a rethinking from linear to more systemic perspectives has been considered important, and research has identified a vast heterogeneity of actors, with private R&D playing a major role, and a shift to a networked knowledge structure (Meynard and Casabianca, 2011; van Dijk and van Boekel, 2001).

As an alternative to linear models of innovation, the AKIS – Agricultural Knowledge and Information System – was conceptualised and introduced in the 1990s (Röling, 1992, cf. SCAR, 2012; Klerkx et al., 2012). It emanated from an interventionist policy approach following the notion that innovations should be strongly coordinated to accelerate modernisation in agriculture (Klerkx et al., 2012; Engel, 1995). To achieve this, the AKIS applies an extension view and concentrates on four main actors in the joint production of knowledge and technologies (Klerkx et al., 2012): research, extension services, education and training, and support systems. According to this model, all of these actors focus on demand from farmers to generate technologies that are suited to farmers' livelihoods (Klerkx et al., 2012; SCAR, 2012; Knickel et al., 2009). The AKIS rapidly attracted critics, who argued that this expert system would fall far short of achieving satisfactory results, even in countries where it was fully implemented, as it would react too slowly to the changing conditions of the public interest and the sector itself (Knickel et al., 2009; van der Ploeg et al., 2008). Moreover, the AKIS devotes limited attention to other important actors in the agri-food chain (SCAR, 2012), such as agricultural engineering firms, input suppliers, (international) markets and competitors and the influence of other sectors (Klerkx et al., 2012). These are especially relevant in animal production and AM.

Parallel to the AKIS, the concept of Agricultural Innovation Systems (AIS) was developed (Klerkx et al., 2012; Rivera et al., 2006), which was influenced by sectoral innovation system approaches in other sectors. The primary characteristics of AIS – through their perception as 'systems in the making' – encompass a more holistic perspective, focussing on joint development processes along value chains (Klerkx et al., 2012), interactive learning processes and the notion that communication is structured around actions (Hall et al., 2003).

From such a dynamic system perspective, innovations in animal production can be understood as a team effort involving various actors through so-called co-development (Meynard and Casabianca, 2011), innovation co-production (Klerkx and Nettle, 2013) or co-innovation (van Dijk and van Boekel, 2001). The multitude of links between different innovation stages (e.g., fundamental and applied research, prototyping and testing) and the interactions among different actors can lead to knowledge acquisition and mutual knowledge exchange that strengthens the innovative capability of actors — in positive cases (van Dijk and van Boekel, 2001; Meynard and Casabianca, 2011; Hall et al., 2003). To fundamentally contribute to the acquisition of knowledge and the development of innovations that represent satisfactory reactions to the sector's specific demands, European animal research should improve its innovative capability (Rosati, 2011).

In certain cases, the concept of AIS is applied to depict national systems and derive options for interventions and public policies. Regarding animal production, this application has proceeded the furthest in the Netherlands and Australia, as reflected in scientific literature on innovation mechanisms in AM and PLF: Klerkx and Nettle (2013) focus on innovation co-production processes in the Australian and Dutch dairy sectors and analyse the achievements and challenges of innovation policies and support initiatives. Innovative actors require strong institutional support to ensure successful co-production (Klerkx and Nettle, 2013). Eastwood et al. (2012) investigate the learning processes of Australian farmers during the implementation and application phase of precision dairy farming technology (decision support systems). However, these publications address individual elements of AIS, highlighting specific aspects of AM or PLF. An overview at the international level concerning the constraints to implementation on farms and the