University research enters practice – and is enhanced by farmers. A Precision Farming case study

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Abstract
This paper describes the case of a Precision Farming technology, the Yara N-Sensor. This more than 15 years old successful university research based innovation has since been supplemented by two modules which have been co-developed by farmers. Today, the optical crop sensor is used for site-specific nitrogen, growth regulator and fungicide application deriving optimum site-specific application rates which are sent to the spreader or sprayer. The most important impacts of the N-Sensor are efficient use of inputs, higher yields and a better harvesting performance.

We trace the innovation's impact pathway from the initial research proposal to the current adoption on estimated 700,000 ha of agricultural land in Germany. Based on a dissertation project running from 1994 to 1996 at the University of Kiel, the innovation was brought into practice by Yara, a mineral fertilizer producer, in 1999. It has since been constantly enhanced, not only by Yara but also by a German SME named AgriCon. The latter company is responsible for sales and marketing in Germany and became a co-developer of the sensor through the development of the two additional modules together with farmers.

For the case of the YARA N-sensor, we detect enabling factors and barriers for innovation. Based on these results we draw conclusions on what we can learn from the presented case on how to foster the innovation diffusion and related knowledge co-production and learning processes. Closeness and proximity to farmers seems a key factor in this respect.

Keywords: Impact pathway, Precision Farming, Knowledge co-production, Transdisciplinarity, Multi-actor networks, Learning networks, Interactive Innovation

1. Introduction

In recent years the Common Agricultural Policy (CAP) and Horizon 2020 have put renewed emphasis on agricultural research and innovation. At the same time there is a broad variety of Agricultural Knowledge and Innovation Systems across Europe (Knierim et al., 2015). In all these systems research based innovations need to find their way into practice and there will be no one ideal solution on how this works best in different systems. Still we can learn from innovations which are today successfully applied by tracing back their impact pathways and detect enabling and disabling factors.

The EU FP7 project "Impact of Research on EU Agriculture" (IMPRESA) intends to measure, assess and comprehend the impact of all forms of European sustainable research on achieving key agricultural policy goals, including farm level productivity but also environmental enhancement and the efficiency of agri-food supply chains. One activity to rise to this challenge was carrying out studies on a small number of cases of mature research based innovations.

One of these studies was conducted on a precision farming technique in crop production, the Yara N-Sensor. The optical crop sensor for nitrogen application was initially developed at the German University of Kiel in the end of the 1990s. It was produced and has been constantly enhanced by the company Yara. In Germany, and nowadays a number of other countries, it is supplied by the spin-off company Agricon. Based on self-driven tests and experiments by farmers Agricon co-developed two additional N-Sensor modules for applications to growth regulators and fungicides (fig. 1). In Germany, the N-sensor is currently used by around 730 farmers on around

700,000ha UAA (Utilised Agricultural Area), with a main area of distribution on farms with more than 500ha.

The paper starts with an outline of the case. We then describe the IMPRESA methodology and in the following section its application to the case. We will describe the impact pathway and show enabling and disabling factors. Based on these results we draw conclusions on what we can learn from the presented case on how to foster the innovation diffusion and related knowledge co-production and learning processes.

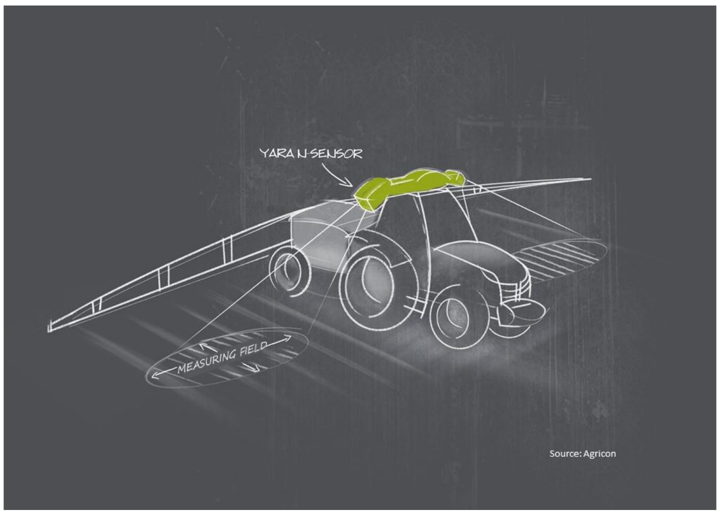


Fig. 1: N-Sensor application of the additional module for crop protection.

2. The case: The Yara N-Sensor

In this section we will present the story line of the N-Sensor from initial research activities, describe its market entry and briefly outline the current situation.

2.1 Initial research activities

The optical sensor is based on a dissertation project within the Institute of Agricultural Engineering of the University of Kiel, where it was part of the Collaborative Research Centre (Sonderforschungsbereich) 192 “Optimisation of crop production systems” and thus funded by the DFG, the German Research Foundation (Heege, 1994). The intended research activities were carried out by a doctoral student who had been recruited from the Departments of Physics at the same university.

In 1996, project results were presented at different meetings and conferences, raising the interest of Yara, formerly known as Norsk Hydro. At that time, Yara (Norsk Hydro) already had a tool for testing the N-content of a plant on the spot, the N-Tester. Like the sensor, it is an optical tool which measures the chlorophyll content of the leaf in order to give fertilizing recommendations. The tester can be considered as a proof of principle raising the interest of Yara to develop an easier way for users to receive more specific fertilizing recommendations for more than one plant at the same time and apply them on the go. Yara approached the University project team and offered a job to the doctoral student at its R&D Centre in Germany, which he accepted after finishing his thesis in 1997 (Reusch 1997).

Product development ran from 1997 to 1999 at Yara, based on the results of the above described research project.

2.2 The innovation enters the market

When the first prototypes were presented, a young German start-up, Agricon, approached Yara and acquired the distribution rights. Since then, Yara works continuously on the adaptation and development of algorithms, control functions as well as further technical developments, while Agricon cares for sales and marketing activities in Germany. In addition, both carry out field trials. Beside these, Yara's direct contact to farmers is rather limited, while Agricon established a close contact to farmers as part of their marketing activities. Together with farmers they continuously work on the development of additional precision farming solutions. The company is located in Saxony and Agricon's other branch, soil sampling, had led to various contacts to Eastern German crop farmers managing more than 1000 ha of agricultural land. As a marketing strategy, the company concentrated on these in the beginning and promoted the pioneers as role models for others.

While the adoption process in Eastern Germany started with the market entry, the number of sensors sold in Western Germany increases considerably since 2008. In 2008 prices for inputs started to increase which served as an entry point to the N-Sensor on Western German farms (fig. 2).

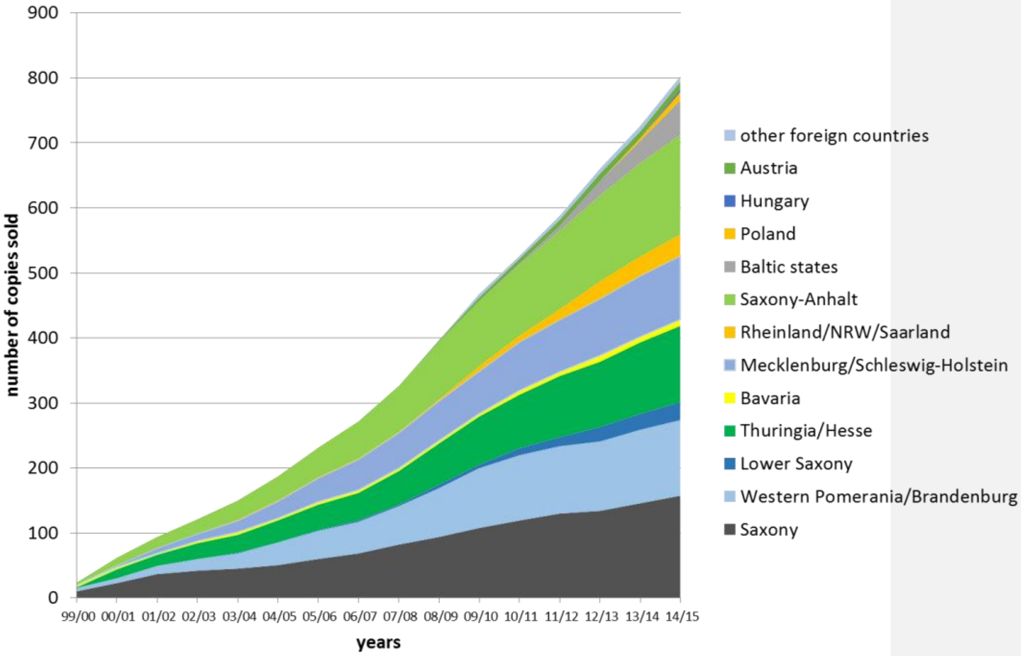


Fig. 2: Cumulated sales figures from 1999-2015 for Germany and other countries, in which Agricon is distributing the N-Sensor (Authors' illustration).

2.3. Today's situation

Currently 1500 copies of the N-Sensor have been sold worldwide, 800 by Agricon, 713 of these are applied in Germany, the rest has been purchased by farms in Austria and Eastern European countries where Agricon currently develops a market (fig. 2).

Within our case study we carried out a user survey. In average users are 50 years old with a variation from 16 to 68. Three quarters of them graduated from universities or applied universities. There are farms with a big field plot size, with up to 10,000 hectares being cultivated by one farm. The survey shows that the average farm size of N-sensor users is around 1350ha, half of the user farms, however, have less than 1000ha.

Most advisory services related to the N-Sensor (and other Precision Farming solutions) are provided by the company consultants of Agricon. Only in some Länder a small number of other adivsors can be found who are knowledged in Precision Farming solutions.

3. How to detect impacts of innovation: The application of IMPRESA's stepwise approach

In the early 2000s the impact pathway method was suggested and applied by different authors mainly from the field of agricultural development cooperation, like Douthwaite et al. (2003) and Springer-Heintze et al. (2003). The intention was to better capture remote parts of the traditionally applied logical framework. Douthwaite et al. (2003) proposed to have the project participants themselves draw an impact pathway in the beginning of the project and carry out monitoring and later ex post impact assessment, with the impact pathway as explicit theory of how the project will achieve impact. This is *'particularly useful in view of the new perspective on impact, which conceptualizes technical change in agriculture as a complex process involving feedback loops, and interactions between social, cultural and biophysical systems*' (Briones et al., 2004:561). If drawn when setting up the project the pathway will make explicit intended outcomes and impact, which serve as a basis for setting up indicators. These can be measured in the course of the project. During the project's lifetime the impact pathway will evolve and gain complexity, but stakeholders as "owners" of the impact pathway will be able to follow it easily. Carrying out the ex post impact assessment the evaluator is supposed establish plausible links between the project's impact pathway and subsequent changes (Douthwaite et al. 2006). Within the IMRESA project we tested the transfer to ex post impact assessment of agricultural research projects and followed a case study approach in order to reconstruct the impact pathway of a research based-innovation. A stepwise approach was elaborated which was applied for all of the six case study regions (Stigler et al., 2014).

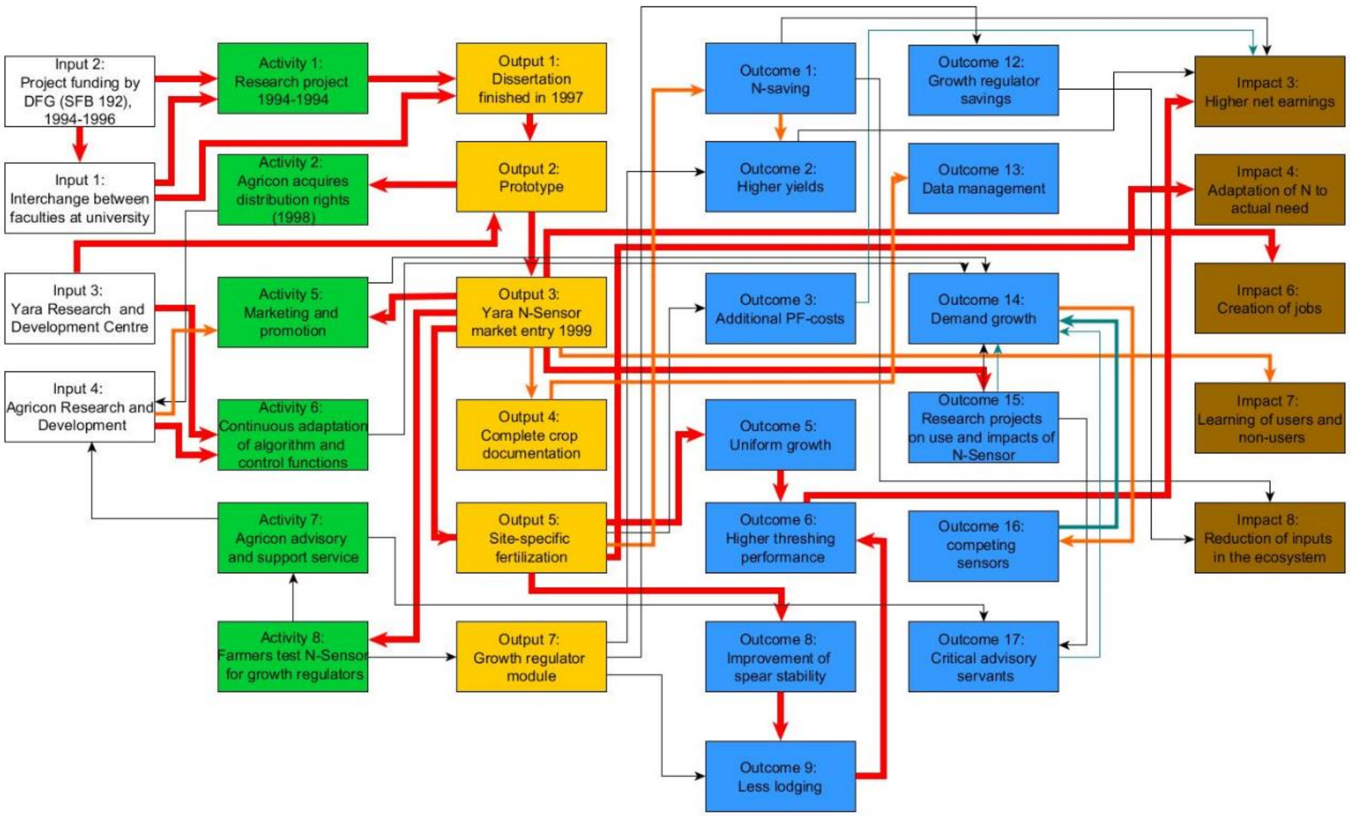
In the German case, research work was organised along the steps which were adjusted case-specifically, reflecting the availability of actors, literature and data, etc. An initial screening comprised a review of literature on adoption and impacts of the N-Sensor as well as explorative in-depth interviews with experts in the field of Precision Farming (PF). We then started with the process of impact pathway building based on literature and semi-structured interviews with key-stakeholders. The 'Sectoral Study on the Analysis of the Innovation System of the German Agriculture' conducted by Bokelmann et al. between 2010 and 2012, published in 2012, was of special help: With financial support of the Federal Institute for Agriculture and Nutrition, the project consortium analysed a broad set of literature, interviewed experts and held Delphi-rounds and expert workshops (Bokelmann et al., 2012). Adding to that, we analysed in our case study a broad set of literature specifically on effects of the N-Sensor and carried out our own interviews with key stakeholders. In order to evaluate the impacts, we carried out a full user survey and held a workshop with farmers, advisors, product and sales managers. The impact pathway was drafted by the case study team first and then reflected with stakeholder and expert judgement (via interviews, survey, workshop). This deviation of Douthwaite's methodology was necessary as our work collided with the field work peaks of farmers, but was justifiable due to the good set of available literature both on the innovation system and the effects of the N-Sensor, as well as the available project documentation in combination with the in-depth interviews. Each link of the pathway was tested against counterfactual reasoning (if it wasn't for the sensor, would it have occurred) and strong links were made visible graphically by more width and colours (fig. 3). The pathway reflection led to crossing out of elements if the attribution to the innovation was not confirmed.

4. The impact pathway of the Yara N-Sensor and its enabling and disabling factors

The impact pathway was drawn along the story of the N-Sensor and was drafted chronologically in earlier versions. In order to allow better readability, it was then rearranged along the traditional linear causal chain from output to impact, the so-called logical framework. It becomes obvious that there are multiple interlinkages between the different pathway elements, underlining the often voiced criticism against the linear chain (Douthwaite et al., 2003).

We present the results of the pathway according to the impacts we were able to confirm. We then give an overview on enabling factors and barriers influencing the impact pathway.

Fig. 3: Impact Pathway of the N-Sensor. The strength of the arrows and the colour shows the contribution of the research to the respective link (black is weak, orange is middle, red is strong).



4.2 Impacts of the N-Sensor

There is a broad set of literature available on the effects and impacts of the N-Sensor. While Agricon continuously carries out own field trials in order to gain more insights on the effects of the N-Sensor and thus be able to use them as selling arguments, universities, consulting companies and advisory services showed as well an increasing interest in finding out if and in what way fertilizing was improved by the use of the N-Sensor. The minimum design of those studies is an annually repeated testing of N-Sensor fertilizing compared to standard fertilizing on a number of plots.

Early studies (Wenkel et al., 2002; Lenge, 2003; Rademacher, 2004; Rösch et al., 2005; Feiffer et al. 2005) show impressive effects of the use of the sensor in terms of N-savings in comparison to standard fertilizing. For winter wheat for instance, the amount of fertilizer used is reduced between 2 to 18% (Rösch et al., 2005:103). Wenkel et al. (2002:258) report 14 kg/ha which equals 7% reduction of N-fertilizer. Rademacher (2004:198f.) shows a saving of 14 kg/ha with a small loss of yields between 0,7 und 4 dt/ha. On the other hand, Reckleben & Isensee (2005), Rösch et al. (2005) and Feiffer et al. (2005) detect an increase in yields: Feiffer et al. (2005:117f) for example report 7% higher yields with 14% less N-savings. These results are supported by the user survey, which was conducted in the frame of the IMPRESA study: Most of the users report N-savings. Nonetheless, there is a need to differentiate between different crops, because for some crops high N- savings can be observed, while for others these may be negligible low (workshop statement).

Generalizing it can be stated, that site-specific fertilizing leads to the adaptation of N to the actual need of the plants (Pahlmann, 2011). The results depend, however, very much on land and weather conditions: If there is extreme dry weather or if there are dry areas with low groundwater conditions, there is a threat of over-fertilisation (Kock 2013; Schliephake, 2007; Schneider and Wagner, 2007; Rösch et al., 2005). The workshop attendees point out, that although the N-Sensor is used, the farmer needs to apply his agronomic knowledge and has to calibrate the sensor according to conditions. Agricon tries to support users, especially on taking into account weather conditions, by sending out regular newsletters to all users.

After first harvesting periods, combine harvester drivers reported that harvesting was easier in stocks which had been fertilized with the N-Sensor. Based on these observations, the Harvest Pool carried out studies and found that stocks show a more uniform growth (Feiffer et al., 2005). In addition, the spear stability is increased leading to less lodging (Feiffer et al., 2005, also reported by Lenge, 2003). Improvement of spear stability, less lodging and uniform growth, lead to a higher harvesting performance. A performance increase of 15-20% for different crops was reported. At the same time, a broader harvest window of around 5 days more time for harvesting was observed. In the user survey we conducted, user statements validated the better harvesting performance (82%), whereas the broader harvest window was not observed by users (71% state there was no change, while 8% observe a slightly broader and 8% a slightly smaller harvest window).

In the impact pathway logic, the application of the N-Sensor for site-specific fertilizing has led to the outcomes harvesting performance, N-savings and higher yields which contribute positively to the impact “Higher net earnings”. Investments for the N-Sensor start at about N-Sensor 26,000€ N-Sensor, the ALS at 39,700 €, additional costs may comprise investments in machinery as a prerequisite for the use of the sensor (e.g. a new fertilizer spreader), as well as maintenance and advisory services (Kock, 2013 calculates an additional 5-13€/ha in comparison to standard fertilizing for winter rapeseed and winter barley). As every investment in agricultural machinery, these costs have to be taken into account calculating the net income. According to Agricon, 100ha of land for N-Sensor use is the current threshold at which the purchase of the machine is worthwhile.

Research on the effects is being carried out continuously; nowadays the results are more moderate. Agricon officials assume that there has been a learning process of users: The effects are measured in comparison to constant N-fertilizing and it is hypothesized, that test farmers have adjusted constant fertilizing due to experiences with the N-Sensor. The workshop participants supported this assumption: Due to the fact that the N-Sensor and meanwhile other sensors exist, farmers even if they are not using a sensor have been hinted on the fact that it might be profitable to adjust the N-application to the actual plant and soil conditions. Especially publications in farmers' magazines but also discussions between farmers have broadened the mind-set and led to a more site-, weather- and soil- specific thinking instead of following fixed fertilizing schemes. Beside the fact that there is the impact "adaptation to the actual need of the plant", we can conclude the impact "learning of users and non-users", i.e learning of adopters and those who have not (yet) bought a sensor.

Since 2006 several enhancements have been made. Yara launched the N-Sensor ALS (Active Light Source), which worked in a similar way as the classic N-Sensor but has its own built in light source (Xenon flash lamps) enabling sensor operation independent from ambient light conditions. In the late 2000s some farmers tested other uses of the N-Sensor, first on growth regulators then on fungicides. All of these experimenting farmers had a long client-relationship with Agricon. Their problem-oriented research was crucial for the development of the module or as one farmer puts it: "*We pushed Agricon to take up our own trials with growth regulators and develop a module for it*". Based on farmers' positive results Agricon developed the module for the sensor. The additional application entered the market in 2008. Leithold & Volk (2007), Volk et al. (2012) and Volk (2015) report higher yields and less lodging, both outcomes contributing to a higher net income. In addition, they report a reduction of use of growth regulators, which is supported by the survey we conducted. Together with the N-savings we therefore summarized as an impact "reduction of inputs in the ecosystem".

The development of and continuous work on the Yara N-Sensor has led to the creation of jobs. The precise number can only be estimated. Interviewees and workshop attendees estimated that around 50 jobs have been created.

There are two environmental impacts, which we hypothesised resulting from the site-specific fertilizing and N-saving: The project proposal (Heege 1994) intended to contribute to higher groundwater quality due to reduced nitrate leakage. In addition, Pahlmann (2011) found a reduction of greenhouse gas emissions if used for the production of rapeseed biodiesel. Both impacts were ruled out by the workshop as they were hard to detect, not really measurable and attributable to the N-Sensor and depending very much on soil conditions.

4.3 Enabling factors within the Impact Pathway

The most important factor for the development of innovations and their adoption seems to be in our case knowledge exchange: between disciplines, between science and industry, between the sales company and customers, i.e. farmers, and between farmers themselves.

The intra-university exchange between disciplines, agricultural engineering, crop sciences but also physics laid the foundation for the successful project. After the first prototype had been developed contact opportunities like fairs and exhibitions as well as conferences were crucial in order to spread the idea and bring scientific knowledge into practice. Meanwhile networks between science and industry have established: Agricon for example seeks direct contact to scientists and works together with them in different networks and projects or provides information if there are requests for support or knowledge. Thus, it is able to keep up with developments in the field and can react to findings.

Exchange with and between farmers seems of special relevance: Agricon has an elaborated marketing and sales plan in which around three quarters of activities focus on direct contact and exchange with a special focus on peer-to-peer contact and information. They organise, for example, regular meetings between users, seminars for drivers, hold webinars etc. Advisory services of Agricon helped to establish contact to both experimental and "lighthouse" farmers, for whom Agricon sets the scene e.g. as testimonials in farmers' magazines. The IMPRESA survey showed that the buying decision was strongly influenced by exchange with other farmers like neighbours or other colleagues. 62% of the users had recommended the N-Sensor to other farmers, 42% even demonstrated the N-Sensor to others. In addition, experimenting farmers exchanged frequently informally and thus pushed each other in testing and improving new ways of application leading to the two modules.

Around 750 copies of the N-Sensor have been sold in Germany. Based on interview statements and our own survey we assume, that nearly all of the big farms cultivating more than 1000 ha in Germany have at least one sensor. The adoption of the N-Sensor seems to exemplify the hypothesis of Bokelmann et al. (2012) stating the capacity to innovate correlated with the size of the farms: Larger farms have the financial resources for the considerable investment; in addition, the return on investment is higher the more hectares are being cultivated; and the education level of farm managers of these large Eastern German farms is generally high. The workshop attendees added that due to higher personnel resources farm managers, or those responsible for crop cultivation, have more time to inform themselves about innovations and they have personnel which can be trained on the use of the machine – in contrast to most farm managers in Western Germany who often run one-man-companies. Smaller farms on which the N-Sensor was adopted are often run by well-trained, prospective thinking farmers which have a technical interest. They are often part of the tinkering or experimenting farmers who bring about incremental innovations (Bokelmann et al. 2012).

While the adoption process in Eastern Germany started with the market entry, the number of sensors sold in Western Germany increases considerably since 2008. Interviewees and workshop attendees hinted on the fact, that prices for inputs started to increase in that time, so there seems to be a direct influence of market prices and margin calculations – making the prospective return on investment more attractive for smaller farms, too. This is reflected in our survey, in which half of the farms cultivate less than 1000ha, 30% less than 500 ha, illustrating that the N-Sensor is increasingly interesting for comparatively smaller farms. On the other hand, experts hint on the fact that the investment behaviour of farmers is volatile and may change from year to year.

The adoption process is also influenced by the respective innovation system. Though criticism has been voiced against Roger's theory (e.g. Robertson et al. 1996) we still borrow his two definitions of heterophilous and homophilous innovation systems (Rogers (1962) quoted after Stigler et al. (2014)), as they are helpful in our context and case. In heterophilous systems, changes from system norms are encouraged. The continuous manifold interactions between people from different backgrounds create a space for new inputs. In these systems, change agents can focus on targeting 'the most elite and innovative opinion leaders and the innovation will trickle-down to non-elites. If an elite opinion leader is convinced to adopt the innovation, the rest is going to adopt it. The domino effect begins with enthusiasms rather than resistance' (Stigler et al. 2014: 47). Examples of heterophilous systems seem to be Saxony and the Rhineland. The opposite are homophilous systems which tend to preserve system norms. Interactions remain mostly between people from similar backgrounds. There is an aversion to innovation as ideas differing from the norm and people thinking outside the box are considered strange and undesirable. Change agents have to focus on a wide group of opinion leaders because in these closed systems it is less likely that innovations or new ideas find their way to the ground. A homophile system can be assumed in Schleswig-Holstein. This is also reflected in the research and advisory community: While in Saxony for instance good testing results are achieved and the N-Sensor is advocated by advisors, in Schleswig-Holstein the agricultural chamber, responsible for advisory services there, is involved in research activities showing critical outcomes. Distribution rates in Schleswig-Holstein are accordingly low.

Another enabling factor is the innovation capacity and innovation willingness of farmers, which has increased in the last 20 to 30 years, due to the higher education level, the increased market pressure and changing requirements and expectations of society (Bokelmann et al., 2012). Correlating age and year of purchase of the N-Sensor, our survey shows that farms now innovate quicker, i.e. more often than just with the change to the next farmer's generation, as it often was the case in the last century.

4.4 Barriers

Beside enabling factors in the innovation systems we also found barriers in the impact pathway of the innovation.

One of the most important barriers internally are technical and knowledge-based related problems of farmers with the system. In the IMPRESA survey, 72% of the farmers say that working themselves into the system was moderately laborious and 13% found it very laborious. We even had a small number of farmers answering the survey who had stopped using the sensor and often it was related to the handling of the sensor. In order to use it properly, drivers need additional knowledge on the different application opportunities and the technical features of the sensor. Agricon tries to close the knowledge gap through different dissemination and advisory activities and offers training, but still drivers need the cognitive capacity to be able to operate the machines correctly.

Since its market entry the N-Sensor has been enhanced, and currently more than 100 algorithms, different crops and different forms of application are possible. In addition, smart cloud and software solutions have been made available. All of this adds to the complexity for users. In addition, farmers need to apply their agronomic knowledge and they have to be able to calibrate the sensor according to (land and weather) conditions. This might be easier for Eastern German farmers who usually have personnel resources and more time to get familiar with a new technique than the typical Western German one-man-company or family farm.

If a homophile innovation system (Rogers, 1962, quoted after Stigler et al., 2014) prevails it may serve as barrier, too. Even if a farmer is located in a heterophilus innovation system, critical studies and critical advisors may considerably lower interest in adoption. In our survey we found, that it took an average five years from the point of time when a farmer first learned about the N-Sensor until he actually bought a copy of it. During this span of time farmers seek contact to colleagues, they read magazines, some see a presentation, others test it etc. Any critical study, testimonial or remark of an adviser may influence the buying decision. Even if these are controversial themselves. Especially some advisers seem to lag behind in terms of knowledge on new agronomic and Precision Farming developments and rather stick to classical pieces of advice.

A future barrier may be the growing share of users leading to a situation where Agricon has introduced a hotline for farmers who had been dealt with before as preferred customers, being able to contact 'their' Agricon advisor directly whatever question or remark they had. This may lead to the frustrating feeling of being 'downgraded' to a normal customer and may lower the closeness between Agricon and farmers which had proved to be positive for incremental innovations.

5. Learning from the case

The Impact Pathway analysis sheds light on impact as (technical) change in agriculture through complex processes and interactions between social, cultural and biophysical systems (Briones et al., 2004:561). The result is a complex impact pathway which has evolved and gained complexity through the project's lifetime, but stakeholders as "owners" of the impact pathway will be able to follow it easily. We found limitations if applied to ex-post impact assessment of mature innovations. Due to a collision with field works peaks of farmers and other stakeholders, we scratched a first version of the impact pathway based on the intended impacts in the proposal, a review of studies on the effects and interviews. Though justifiable from a content perspective (good set of available literature, available project documentation, rich in-depth interviews), it created the difficulty for stakeholders to follow the naturally complex pathway of this mature innovation when we finally presented a first version to them. For better readability we rearranged the pathway along the logical framework (which we considered outdated and initially didn't want to have a slightest notion in our pathway). Nevertheless, drawing the impact pathway helped us taking into account a broad range of elements and reflecting, as well as representing in the graph, the manifold links between these.

The analysis of enabling factors and barriers led us to the question on how to create space for innovation and what prerequisites needed to be there in order to foster knowledge co-production processes. One main element might be stimulating the evolvement of heterophilous systems through leveraging continuous manifold interactions between people from different backgrounds. This will create space for new inputs, which in the end encourages changes from system norms. The experiments of the farmers were only taken up by Agricon because of the close personal contact to these farmers: There was so little distance between the two parties that farmers felt allowed and able to push Agricon take up their trials, and on the other side Agricon had enough trust in the abilities and knowledge of these farmers to rely on their tests and initiate the development of the two modules. Thus we can conclude in line with Bokelmann et al. (2012), referring to Koschatzky (2001), that close proximity and socio-cultural networks help reducing uncertainties in the innovation process, which is especially valid for complex technologies. The success and high innovation capacity of SMEs like Agricon is based on the strong integration in rural networks and their closeness to customers.

In addition, the case illustrates the need for independent advisors. They can play a key role in mainstreaming Precision Farming inventions like the N-Sensor and thus helping it to become an innovation, i.e. a new practice which is widely accepted. Our case illustrates the current situation (cp. EIP AGRI FG Precision Farming, 2015) that Precision Farming technology transfer is mostly left to private, often company consultants like Agricon. These pieces of advice, however, will always be conflicting with their own marketing agenda. Advisers need appropriate training and knowledge on Precision Farming solutions in order to be able to perceive the potential to improve advisory services by improving management and the efficient use of resources and help farmers to set up the most appropriate farm management system causing as little frustration as possible (ibid.).

There needs to be continuous exchange and communication at various levels: between disciplines at university level, between science and industry, etc. Of particular relevance is regular and close contact to users with communication as equals. All of these communication processes require time, opportunity and communication skills, but in the end they will broaden the mind-set – and foster interactive innovation.

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