The legitimacy of precision livestock farming

– in conversation with the Swedish research community

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Abstract

Precision livestock farming (PLF) is gaining popularity in the Agri sector across the world. The aim of this paper is to understand how PLF is perceived by researchers involved in the development phases as well as looking at PLF from a product category legitimacy framework developed by Bork et al. (2015). The research was conducted with semi-structured interviews with 5 researchers from the Swedish University of Agricultural Science and the RISE research institute. The analysis of the material shows a lack of common understanding regarding the purpose of PLF from different researchers. The material also highlights the potential that PLF has for all production. This includes both small and large-scale farms, although small-scale farms might be facing bigger implementation barriers than large-scale farms. Regarding access to data for PLF, access is limited and there is little regulation as of yet for data ownership and data sharing. The material shows that PLF as a product category is not fully legitimized yet but still fulfils some legitimacy criteria.

Keywords: precision livestock farming, PLF, Agri sector, digitalisation, legitimacy, AKIS, smart farming, livestock, agriculture 4.0

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Abbreviations

SLU	Swedish University of Agricultural Sciences
PLF	Precision livestock farming
R&D	Research and Development
AKIS	Agriculture Knowledge and Innovation Systems

1. Introduction

During the fall of 2020, I took a course at SLU on Precision Livestock Farming (PLF). I was interested in learning more about the use of technology and data science for farm management and food security purposes. The course focused on different types of technology used for a variety of livestock, and it mostly framed PLF as tools, from their ideation to their implementation. An example of such a tool is the milking robot used in the dairy industry. What I found the most intriguing with PLF was the fact that it seemed to stand in contrast to notions of farming as a practice that shines in its tradition and long-standing practices. It seems that farming, as an industry, is aiming at benefiting from automation and artificial intelligence trends as experienced in other fields. With PLF, one can rely on technology for advice on how to better manage livestock. There appeared to be a lot of benefits with PLF, and like many revolutionary processes, precision livestock farming is often framed as a solution for many problems. It seemed crucial to paint a nuanced picture of the potential of PLF. It felt important to pay attention to the complex socio-ethical aspects of any type of automation. As we move forward into a more complex, digitally rich farming system, we will face unforeseen challenges and opportunities, and PLF is part of that transformation. The reliance on technology as a substitute for labour has the potential to reshape the rural landscape.

1.1. Purpose and research question

During research and development (R&D) phases of new technology, multiple decisions, big and small, needs to be taken. For PLF, these decisions ranges from which data to collect for machine learning purposes to what type of sensor is most appropriate, and everything in between. These R&D decisions help create a product with a goal to impact farming practices. With that in mind, I wanted to investigate how actors involved in R&D processes viewed the purpose of PLF and what it meant in terms of the legitimacy of new products. A set of three main research questions have been selected. The questions are the following:

- What purpose does precision livestock farming serve?
- In what context can PLF be implemented and are there barriers to implementation?

- How do researchers interact with data, and how do they view the access and management of it?

2. What is precision livestock farming?

Precision livestock farming, or PLF, has been defined in multiple ways. For this paper, PLF will be described as a form of real-time process management of farm animals. The real-time management requires monitoring over the animal's health, production/reproduction, welfare, and environment. The type of continuous monitoring in PLF can be done using different technological equipment, for example cameras, sensors or microphones (Berckmans 2017). Berckmans (2017) writes that the idea of process control and management, which is the basis of PLF, is to be able to predict how the process output (the variable to be controlled, for example animal health) would respond to a change in the process inputs. An example of that could be the prediction of weight for animals when feed ratios are changed.

In other words, precision livestock farming aims at using equipment to monitor animals to detect problems in their early stage, thus reducing the amount of monitoring required by the farmer or layperson. Animals are a complex component of farming. Berckman (2017) writes that a living organism, for example a farm animal, is called a *CITD System* with CITD standing for complex, individually different, time-varying, and dynamic. Berckman (2017) highlights the complexity of living organisms, and how in biological research it is common practice to compare groups of living organisms by looking for statistical differences in experiments. Statistical methods are primarily used to find significant differences in the averages of groups. Berckmans (2017) strongly underlines the fact that this theoretical average of a group is not an infallible reference for how living organism act or behave. The time-varying part of the CITD System means that the animal will not necessarily react the same way each time, even if the input is the same. This means that when developing real-time monitoring tools, special attention needs to be given to the chosen algorithm so that it adapts to the individual organism (Berckmans 2017).

The equipment used in PLF also plays a role. Generally, sensors are used in PLF to collect real-time field data, or bio-signals (Berckmans 2017). Examples of such sensors includes thermal imagery, microphones, GPS positioning, etc. The data collected from sensors is of astronomical size, and algorithms are often required to analyze the relevant data in an efficient way. Berckmans (2017) explains that there are two main way to handle data. The data could either be directly processed and instantly relayed to the farmer. An example could be a tool that starts an alarm when the temperature of cows drops below average. Another way could be that the information is passed through a type of data service company that could analyze it and send feedback to the farmer.

3. Theoretical framework

To analyze the material collected through interviews, I decided to follow the product legitimation framework presented by Bork et al. (2015) for new product categories. This framework is relevant as precision livestock farming gains traction worldwide. The material will also be related to the concept of Agriculture Knowledge and Innovation System (AKIS) to give context to how new product categories within the Agri sector are developed and deployed. The motivation behind the choice of framework was that many components of the legitimacy framework apply when discussing the upsides and downfalls of precision farming. This is both from a socio-ethical perspective and what it means for the general acceptance of the products. In the context of legitimacy, the consumers of PLF products are in this thesis considered to be farmers.

3.1. Product legitimation framework

When framing PLF technology as a new set of products entering the market, one must question how it is being legitimized, as this will set the context for the product category moving forward. A product category can be, for example, electric transport which then encompasses products such as electric cars, electric buses, etc. In the product category of PLF, the products can for example be accelerometers, milking robots, heat sensors, etc. As expressed by Bork et al. (2015), legitimacy of the category allows for the adoption of the products within the category. The purchase and use of a product is what is meant by adoption. Legitimacy is required for a product category to become relevant in the market and to be widely adopted on a large scale. In line with this, legitimacy provokes a growth in demand (Bork et al. 2015). Bork et al. (2015) define legitimacy for new product category as the following: ‘The generalized perception or assumption that the use of a certain product category is appropriate, proper, or desirable within a certain context of physical objects and elements and some socially constructed system of norms, values, rules, beliefs, and expectations’. Beliefs and social norms within a system, in regard to a new product category, will influence how the new category will be judged. The need for pre-existing socially accepted beliefs, norms and practices for legitimization of new technology also comes hand in hand with a need to fit in the local context. This is because, as Bork et al. (2015) states, not all technology will be accepted in all locations due to differences in physical environment, cultural underpinnings, and social structures. The legitimatization process, which involves broad system change, also requires

actors with different vested interests to interact with each other (Bork et al.. 2015). As Bork et al. (2015) mentions, efforts from involved stakeholders and changes in physical and social context can facilitates for the legitimacy level to increase over time. The involvement of different actors in the process can create conflict due to different interests or motivations. Bork et al. (2015) identifies the five following legitimacy factors**: comprehension, value, compatibility, validation, and procedural justice.**

Comprehension refers to the extent of awareness of consumers regarding a new product category and if they understand it. When a product category is taken for granted, it means that it has reached peak comprehension. Bork et al. (2015) states that a collective and coherent perception amongst stakeholders is required to positively influence comprehension.

Value is the consequence of a new product category and the meaning associated with it. It can be both positive and negative. Bork et al. (2015) uses electric cars as an example: low emissions are a positive while limited range is a negative. The value associated with a new product category can be either of pragmatic value or moral value, where pragmatic value is of self-interest while moral value relates to benefiting society as a whole.

Compatibility is described by Bork et al. (2015) as 'the relationship between a new product category and the physical and social context in which it will be used'. For legitimacy of a new product category, there needs to be space for it to fit within the physical environment it is to be used in as well as with the pre-existing norms and values.

Validation is explained by Bork et al. (2015) as 'the establishment of a collective evaluation of a product category'. This means the communicative process or signal of approval of a new product category. The authors give as an example the adoption of a product by other consumers as a form of endorsement which pushes validation. Another part of validation is to see a unified support of the new product category from different stakeholders. This can be done for example with tactics such as subsidies that encourage the adoption, or a change in infrastructure (i.e. the presence of charging stations for electric cars).

Procedural justice, as described by Bork et al. (2015) refers to the perceived fairness of processes and procedures. It is to be understood that the production of a product category must feel fair and just if it is to be legitimized. The fairness, or lack thereof, can be both positive or negative in terms of legitimizing a new product category. Bork et al. (2015) gives as an example the deforestation caused by the development of biofuels as a negatively impacting procedural justice. Fairness and justice of process is important to foster trust. Procedural justice also comes into play when laws and regulations are used to regulate the usage or the production of a product category. Bork et al. (2015) gives the example of the introduction of tax exemptions for electric cars in the Netherland as an example of governmental involvement, through laws and regulations, which helps with legitimacy.

3.2. Agricultural knowledge and innovation system (AKIS) paradigm

To add context to the new product category of precision livestock farming, the broader history of innovation in agriculture needs to be touched upon. Agriculture innovation is characterized as a co-evolutionary process, i.e. combined technological, social, economic and institutional change (Klerkx et al.. 2012). Klerkx et al. (2012) explains that agriculture innovation requires not only new technology but new technical practices and alternative ways of organizing. The theoretical perspective on agriculture innovation has shifted through the years. *Adoption and diffusion theories*, which first emerged in the 1960s, are social in nature and is linked to transfer of technology, meaning innovations are spread through word-of-mouth within different communities while mass media helps push forward the innovation ideas to new territory, leaving institutional and policy context on the periphery (Klerkx et al.. 2012). In response to linear development of agricultural innovation, *Farming systems research* emerged in the 1970's to encourage involvement of farmers in the design phases of new technology done by scientists. Over the years, the involvement of other actors such as policy makers and extensionists has been added to the list of involved parties and the desired outcome of technological advancement has strayed from purely crop optimization to overall improvement of farming systems (Klerkx et al.. 2012).

From the 1990s, the concept of *Agricultural Knowledge and Information Systems* (AKIS) was pushing the boundaries even further to go fully against a linear system. AKIS went through some changes in its definition, from beginning as having clear national sectoral boundaries and common purpose and goals to eventually being defined as a collaboration between actors with different perspectives but who are part of a system together (Klerkx et al.. 2012). It made the farmers be involved in development as experimenters and was thought to empower them so that the new development would better fit their livelihoods. The general understanding behind AKIS is to recognize the importance of transferring information from farmers to research systems while recognizing that that most technologies will be transferred from researchers down to farmers (Klerkx et al.. 2012).

4. Method and material

4.1. Interviews

The material was collected through a set of interviews with different researchers involved in some way with precision livestock farming. The choice of only interviewing researchers was made so that the material would be easier to compare. Although farmers and their perception and involvement come up often in this thesis, the choice to not include them as potential interviewees was made. This decision was based on the fact that farmers can either be involved in PLF development, or not, which means that the required sample would need to be quite large to cover both circumstances. Digital interviews were qualitative semi-structured interviews. The reasoning is to guide the interviewee through a set of questions while allowing them to raise their own perceptions and concerns regarding the subject. The interviews were conducted with a set of researchers from 2 institutions, which are the Swedish University of Agricultural Science and the RISE institute. The interviews were conducted over ZOOM and lasted approximately an hour each. A set of questions was prepared for the interviews (see appendix), but some questions were presented differently depending on the specific field of work of the interviewee. Not all questions were asked to all interviewee as it became clear that it could be repetitive or not relevant to the interview.
All the questions were asked in English, which is not the native language of most of the interviewees. Notes were taken during the interview as well as audio recordings.

4.1.2 Ethics and practicalities

The interviewees were notified of their anonymity and asked whether they consented to the use of direct quotations. They all agreed. Although the interviews were anonymous, it is important to acknowledge the risk associated with the fact that precision livestock farming is not a large field of research in Sweden and there is not a large pool of potential interviewees. Some of the researchers interviewed came as recommendations from other interviewees and a lot of the actors are colleagues, collaborators or aware of each other's work. This could be seen as a lack of variation in the material sources. However, as explained, the field of precision livestock farming in Sweden is relatively narrow which explains why a lot of researchers are aware of each other or are collaborators in some form. As one of the purposes of the research is to understand if there is a consensus

between collaborating actors, interviewing collaborators and colleagues is relevant. All interviewees are involved in PLF in some form, but their diverse background contributes to painting a more complete picture when trying to understand all aspects of PLF.

In terms of validity and reliability, the research was done by conducting interviews with one group of stakeholders, the researchers. Their opinion might change over time and it might not be aligned or representative of all other stakeholders in the field. Since all interviewees work in the same field and within the same country, some of their answers might be applicable solely in a Swedish context. Some biases might be present as well, as some of the funding for the research of the interviewees is dependent on a continued support for the development of PLF. The choice of focusing on the research communities facilitates the analysis of the material as they are more similar between each other than with other stakeholders. Thus, their answers can be compared easily. The goal of the thesis is to investigate consensus amongst stakeholders, and that can be done even with a small, homogenous group of actors.

4.1.3 Interviewees

Peter is a researcher at RISE and has worked with PLF for approximately 20 years, starting with how to use technology to best wean cows and then on automatic recording of behaviors and characteristics of animals such as heat or health. For the last 10 years he has worked with automatic recording of cows positioning in the barn.

Lennart is a professor of statistics at a Swedish University and works with research at SLU focusing on precision livestock farming. He is also doing research at the Beijer Laboratory for Animal Sciences. His research at SLU consists of looking at social interaction between dairy cows from 2 farms with 200 animals each.

Gunilla is a researcher at RISE and has been working with precision agriculture for about 25 years, and PLF for about 20 years. She has been working with various applications of image analysis in agriculture as well as information handling, LEAN production introduction in agriculture and some management positions. Currently she is a project leader looking into data-sharing and making insights from data in the beef supply chain.

Christian has been working at SLU since 2018. He has a background in computer science and applied mathematics. He is applying statistics and data analysis to agricultural data sets. He works on the project led by Lennart in terms of looking at cow’s social behavior and relating it to other milk production traits.

Max has both a veterinarian background and IT-background. He is a researcher at SLU and has been focusing since 2014 on PLF algorithm development and innovation, with a focus on deep learning and machine learning for prediction in animal production.

4.2 Analysis

It is important to acknowledge that the answers provided by the interviewees are taken as legitimate and there is no extra fact-checking being done to verify the accuracy. For the analysis of my material, I used a thematic coding analysis. I looked at the interview transcripts and highlighted sentences and quotes that centered around similar themes. The quotes were then ‘clustered’ in a separate document and then were written in a continuous text where the different actors answers could stand in contrast to each other. Some of the answers to certain questions were of a continuous stream of thought and were then broken down and associated with relevant themes. Sorting through the material was done by finding relevancy regarding research question, the chosen frameworks, as well as what I found to be insightful and what the interviewees seemed to want to emphasize during the interview.

5. Results

The result of the interviews is divided in three sections for the three research questions. Particular themes for the questions have emerged and been identified by the use of subheadings.

5.1. What purpose does precision livestock farming serve?

5.1.1 Modernization of an industry

According to most interviewees, the push for digitization within agriculture is part of a general trend for digitization in all fields. Christian explains that funding bodies are providing funds for research in digital transformation, thus more researchers decide to align their work with it. Christian says that the funding agencies, however, are not completely independently thinking – they are influenced by what the general public and the farmers want. Lennart echoed partially this thought, but he added a distinction of a different direction PLF can take

> One track is food security, to follow the food chain all the way from the farm to the store. That's one part. And I guess one sees the need from the consumers, and then to be honest I think it's also companies that see an opportunity to sell product to farmers. (Lennart, 2021)

This is not to say that this digital transition is unique for the Agri sector, as Lennart says, ''farming gets swept up in the digitalization''.

When it comes to the purpose of PLF, Christian sees the technology being developed as a way of applying an individual animal approach in terms of advice and recommendations for farm management. He compares it to the medical system where each patient gets personalized care, and how PLF would allow individual assessment of animals instead of flock-wide management. For Max, the purpose of PLF follows the same vein – a cost effective, energy efficient solution allowing farmers to constantly monitor their animal but also as a way to stimulate curiosity for the adoption of modern technology in the production system. For him, it does not reduce the distance between the farmer and the animal, it just allows for farmer's peace of mind that no matter what happens throughout their

day, there is monitoring, and tracking being done. It is for him a way to preserve the lifestyle of farmers while adapting to modern needs and stresses. For Gunilla, the ‘baseline’ of a farm is explored with PLF, as she explains that PLF helps measure the normal state of a production and the facts about the baseline which gives a clearer view when trying to improve - ‘’You could know that something is not normal but perhaps the not normal is normal because it’s occurring so often’’. On the other hand, Max believes that PLF has other purposes than benchmarking everything, as he states, ‘’we are a minority in the research community that wants to see more of a human-animal relationship be focus of technology than the very effective 24/7 monitored production’’. When it comes to Peter, however, PLF allows insight about animal behavior that would otherwise be missed when not using 24/7 surveillance tools. He also believes that it alleviates the workload and the need for labor for farmers.

Although all interviewees had somewhat diverging answers to their own perception of the main purpose of PLF, when asked directly if all actors involved had diverging views on the matter, the answers were not aligned. Lennart answered that no, he did not notice different views on the purpose of PLF from different stakeholders. Christian said yes, but stresses that it is normal and common to have some differences when working with people who have different perspective. He used himself as an example

> From my perspective I am more interested in methodologies, how to automate it, how to make analysis reproducible, how to share a code and write robust system, but of course farmers are more interested in application and want to have usable tool to increase profit and help them. (Christian 2021)

For Peter, all actors share something in common

> Companies and farmers usually have the same purpose, its process optimization. I am always working from the animal welfare point of view, but farmers are as well. The whole point of having PLF is to optimize production, we want to press out as much as possible out of these animals without jeopardizing their welfare. (Peter 2021)

Gunilla highlights that this all depends on how far away from the farmer you get; if you go to retail then you must look at what the consumer wants, or what they have been taught to want, and it puts demands on PLF that might not align with what the farmer wants. For Max, he sometimes feels alone in his line of thinking and says the following about the field ‘’we have focus on developing things for the sake of developing without investigating the potential socio-ethical economical aspects of what we are developing and that’s why it might stagnate integration and acceptance’’. For him, PLF is not just about the health and welfare of individuals or groups of animals, but also consumer perceptions as well as safety and quality of the products entering the food production chain. Although most answers shared similarities, the role of PLF was perceived slightly differently by all. With that said, not all seemed to agree that there would be diverging views.

5. 1.2 Collaborative process

According to the interviewees, the collaboration spreads wide. All echoed the fact that the development of new PLF technology and ideas often are generated in research institutions, while Gunilla and Peter mentioned their collaboration with the private sector and entrepreneurs. Gunilla mentions that policy actors are also involved. Max turned the question around and asked ‘’Who do I not collaborate with? Everybody from other researchers, large transnational company like SONY with large turnover, or even tiny start up’’. Max is interested in bridging the gap between early adopters and skeptics, which means he puts a lot of focus on working with end-users along the process. For the involvement of farmers as end-users, Lennart, who’s research involves collaboration with two commercial farms, says that ‘’well at least we discuss the things we want to develop with the farmers’’. This is echoed by Peter who says that the development phases are characterized by ‘’talking to the farmers, they are always interacting and telling their point of views what they actually want from the technology and giving really good input to these companies’’. Peter believes that the farmers are interested in new technology, as long as it works and is useable. Both Gunilla and Peter expressed that the companies can develop new technology, but if there is no clear use for it then the farmers won’t adopt it. All interviewees mentioned research institutions as big players in PLF development, and they also mention farmers, but the presence of farmers in the development seemed to be of a lower degree according to multiple interviewees. There is some form of consulting that is done in the R&D processes, and farms need to be involved for data collecting purposes, but through the answers it seemed that the farmers were more of a side character than the ones pushing for the transformation.

Max highlights the need for cross-disciplinary education and communication within PLF as he states that there is a lack of understanding for basic things, even for things such as the definition of PLF, due to a lack of common language.

> A lot of time is wasted when people try to understand each other. I want to see (…) some way to make this communication more effective in terms of what people expect and how they talk to each other. (Max 2021)

He adds, regarding the involvement of different actors in the development of PLF, ‘’We think we know what to expect, it’s completely off when people meet and start doing stuff together’’. The expectations do not match the reality of the collaborative process. According to him, there is no clear consensus as to why we invest and want to push forward PLF. He points out that there seems to be a lack of discussion around soft values brought on by the adoption of PLF. He references a conference that was held in previous years regarding PLF and mentions ‘’(…) from 100 presentations, 96 will be about the proof of concept, if a certain model works and not if its needed or what it can lead do. Little research on what happens when we actually start using the PLF’’. He stresses the following ‘I almost sound anti-technology, but I am not’.

This mismatching of knowledge and understanding by involved actors is highlighted on many occasions by the different interviewees. Even the term PLF is seemingly understood differently by the interviewees. Christian mentions how he thinks the term PLF is not very stable at the moment and how he ‘’would rather describe it as a set of methods’’. When asked a certain question, Peter says

> PLF is not something new – PLF has been working for 30-40-50 years. It’s not something new, it’s just something that is slowly being incorporated into the production with new technologies. It depends on what you mean with PLF, it can also just be data, from the production, that’s also PLF. (Peter 2021)

5.2. In what context can PLF be implemented and are there barriers to implementation?

5.2.1 Adoption tipping point

Lennart mentions

> PLF is in one sense if you want to have large scale production, so if you want to have dairy farm with 600 cows then you definitely need these kinds of tools to keep track of all the animals and everything. On the other hand, it might be very useful for small scale farms as well. (Lennart 2021)

Some interviewees mentioned well-established PLF technology. Peter brings up the accelerometer ‘‘I don’t think any farmers out there are without having an accelerometer on their cows, it is something that’s really standard so they [the farmer] know the activity of the animal’’.

Peter makes a point of including the cost of investment as a barrier for PLF usage on smaller scale production ‘’It’s not a problem to apply PLF on smaller farm, it’s a cost problem’’. It is both an income problem but also an infrastructure problem, according to him. Peter states that if a farmer sees that a technology works and can help them make more money than it costs, then there is no resistance, but there is a need for the product to work within the existing infrastructure, which is not always doable. He raises as an example of a farm where the internet connectivity is not up to par which prevents the usage of PLF technology. Gunilla expresses similar thoughts to Peter, but highlights the need for a coherence across the whole food chain, not just useability at the farm level. She illustrates this with an example of electronic ID tags. If a farmer invests in those instead of regular plastic ID tags, there needs to be a way for them to be readable by sorting machinery for example, in order to either save them time or labor. For slaughterhouses, to take advantage of electronic ID tags, they need to update their production line, but they will not be enticed to do that if its only usable on a small portion of the animals coming through. ‘’Who starts doing the investment?’’ is a question she brings up. This is a line of thought that Christian also has about

turning research into something useable. For him, it's not just about developing new tools that work, but it is convincing farmers to adopt it, which requires resources and common efforts. He frames it as creating a whole ecosystem in which the tool can operate in, such as new policies and support from governments and good marketing tactics. He also believes it is mostly relevant to big production, ''you only get the benefit if it's applied on large scale farms or non-traditional farms''. For Max, the ones who buy the products being developed depend on who sells them ''Bigger companies could have a financial or market buffer to sell to the smaller farms to slowly build up the revenue, while if it's a start-up they will most likely target biggest player to get sold units''. Gunilla points out that the best way to make farmers adopt a new product is to show that it has a benefit ''Any technology that can clearly show the benefit for farmer would be high on an investment list''.

5.2.2 Traditional knowledge vs artificial intelligence

As to whether PLF will increase animal welfare, Peter believes so

> Humans are used to seeing sick animals and might not recognize them, but technology does not. It is better for the animal to be monitored by machine than to be monitored by humans. (Peter 2021)

Gunilla reflects on the idea of 'golden standards' and how they are being implemented in PLF tools

> The golden standards on how to treat animals are being put into the technology, so the technology at their baseline is to have very good animal welfare. Then (…) if the technology is working correctly as it should then it increases the animal welfare standards. (Gunilla 2021)

As to whether there could be personal values and beliefs embedded in the technology by researchers, she sees this line of questioning as somewhat irrelevant

> they [the researchers] might try to but if there is no benefit with it then no farmers would buy it. I think for PLF the question is not that conflicting, because healthy animals also produce better, so if you have sick animals the production goes down, so it is very beneficial for the farmer to have healthy animal as well. It's kind of win-win situation. (Gunilla 2021)

For Lennart, PLF is not something that solves all animal welfare problems for the farmer. He believes that a farmer should be able to tell by themselves if an animal is sick or not or in need of help in any way, as he states that artificial intelligence cannot capture all the signs. For him, it is important that the farmer keeps in touch with the animal. He is also worried about the next generation, as he reflects on how coming with traditional knowledge and adopting PLF tools seems to work fine, but that he is unsure what will happen once the farmers have grown up with technology and rely on it instead of traditional knowledge. He sees a future where farmers could then become less self-reliant. When reflecting on if these tools increase the distance between the farmer and the animal, so that the farmer

doesn’t need to visit the animal for example, or if it actually improves the connection between them, Lennart says ‘‘that depends a lot on the farmer, on how he or she uses the tool I would say’’.

Similar concerns about the way we use PLF tools are expressed by Christian. Regarding traditional knowledge, he believes it should not be completely discarded in favor of artificial intelligence despite how robust the tools are. Christian states the following

> I can say that mathematics is the most objective thing that we have, and so the algorithms are neutral, but the data we feed to algorithm is not neutral, and our interpretation of their output is not neutral, but when it comes to codes it is the most robust. (Christian 2021)

However, he is worried about complete reliance

> If you only rely on algorithm, you can lose the touch with nature and the reality. We will have less and less expert like old and wise farmers that can tell you things, without knowing all the details. They can feel the cow, they have subject knowledge that goes beyond what we can comprehend. (Christian 2021)

The interviewees all expressed the thought that PLF has the potential to increase animal welfare, but not all agreed on if it is better or more reliable at detecting wellbeing than the farmers themselves.

5.3. How do researchers interact with data, and how do they view the access and management of it?

5.3.1 Context of data

Data in all its forms is part of every step along the path of PLF development. Data is collected to develop tools and algorithms, it is also then collected to be analyzed by the algorithms, and it is also given back to farmers for decision support. According to Max, diversity in collected data in the early development of products and hypotheses is important, and it can be done on smaller or bigger scale production as it is ultimately up to the researcher to assure that the data is varied. ‘’ You need to catch up as much variation as possible even on a small scale to make sure the prediction makes sense or that the model converges for example’’. For him, there is a human factor associated with good data sets. Since data is collected on farms, the role of farmers is also important

> It all comes down to how good you are at being consistent with your tools. If you are a good farmer, then most probably all systems are in order and then you get higher quality data. (Max 2021)

. Once the data is collected and ready to be analyzed to develop PLF methods and tools, there is a need to understand it and where it comes from. According to Christian, this is not without its challenges. He states, ‘’we need, as people who analyze data, to know the context, but it’s hard because most of the time we are not the specialist in this particular subject’’.

Christian explains that the quality of collected data relies a lot on the farmer, on how diligent they are, how interested they are in supplying this data for the research. It requires establishing good relationships with farmers or data providers and the need for trust between farmers and researchers is important. Christians states ‘’It’s not just the data, it’s the knowledge about how the farm is performing, about some small problems and specifics which can explain some of the biases that you can see in the data’’. Christian explains that if you do not understand the context, it is hard to understand anomalies. He brings up the fact that to work with data, you need to specialize in it, but that this can be done in two different ways. On one hand, one can be a data scientist that then must learn about a particular subject that they are working on, or, alternatively, one could be a specialist in a field, for example a biologist, and then must learn about data science. No matter what route one takes, it always involves some understanding of the material you work with. He says of himself

> I’m not an expert in cows, but as I analyze data sets, I am learning about cow physiology, cow management and so on. I need to become a small, with limited expertise, (…) expert in a very narrow field. (Christian 2021)

He goes on to say that it also depends on what the goal of the research is. For instance, whether it is to make specific farm recommendations or to predict country-wide milk yields – then how close you look at the context is not as important.

5.3.2 Access to data

As mentioned earlier, data is collected and used in different stages of PLF and for different purposes. While farm data exists in large amounts, most interviewees stressed how hard it is to access in general. Christian says, ‘’When it comes to data sharing, I think we are in stone age, there’s lots of problems like people don’t like to share data’’. For him, it is a matter of knowing the right people and quickly turns into something political. The more papers you have published, and which institution you work for will dictate your ability to have access to data for research purposes. Lennart also raises his concern regarding how difficult it is to have access to data, and he says it is not only a problem in Sweden but it is a worldwide problem. He mentions that there is a desire for better access to data, and gives as an example the work SLU has been doing for a project named Gigacow, where data is collected from milking robots across Sweden and stored in a common database that can be used by researchers. Max mentions companies and advisor organizations sitting on big data silos as a problem, and he believes that no EU country has solved that problem. Data silos prevent the sharing of data, and Gunilla also takes these silos as an example of a hurdle in terms of data-access. Gunilla mentions how the discussion about how to share data is relevant ‘’because data is a special asset, if you share data, you can share many times and

you don’t know where it ends up and that can be a problem if it’s not handled correctly’’. Who owns the data is a big question to which no interviewee has a clear answer. Gunilla mentions how some big companies are following the development and want to own the data, while farmers see the data as theirs and wish to monetize it. It is portrayed as a tug-of-war and the lack of legislation around data is highlighted by the interviewees. The interviewees stressed the need for a more open access to data and mentioned some projects in the work in Sweden, while explaining that we are far from having solved this piece of the puzzle.

6. Discussion

When looking at the collective answers from interviewees, many aspects of the legitimization framework come into play. The categories within the legitimacy framework (validation, comprehension, compatibility, value and procedural justice) all apply to some of the topics discussed with the interviewees, such as adaptation of the food supply chain, adoption hurdles, perception of products from different stakeholders, legislations around data, etc. Each associated category of legitimacy will be used to look at certain parts of the collected material.

6.1. Comprehension

Comprehension refers to the awareness from the consumers regarding a product, as well as their understanding of it. The ultimate form of comprehension is taking a product category for granted. As farmers would be the target consumer of PLF, getting their opinion on the matter would have been of great relevancy. However, as researchers are often at the forefront of product development, their comprehension also plays a role in how this product category is shaped. As mentioned earlier, comprehension also refers to a coherent understanding among stakeholders. What is relevant in terms of comprehension was the lack of agreement from this limited number of interviewees regarding the purpose of PLF and PLF technology. Although some interviewees expressed not being aware of diverging views regarding the purpose of PLF from multiple actors, the 5 interviewees gave themselves diverging answers. Some answers emphasized different part of the food chain – PLF having the benefit to have better transparency in terms of the food entering the market in contrast to PLF being primarily about optimizing production. Although these two aspects do not cancel each other, an optimized production and traceability within our food chain can happen simultaneously, it still represents different focuses for PLF.

Some interviewees, such as Max, expressed feelings of being isolated with his view of PLF being able to increase the animal-human relationship. Gunilla illustrated the diverging opinions herself when she mentioned how the demands on PLF can vary depending on how far away you get from the farmer, as consumers might have different demands or expectation influenced by certain narratives than the people actually working directly with livestock. All stakeholders might want ‘better’ production but what is meant by ‘better’ is

unclear.
As Max mentioned, there is not necessarily a common language when talking about PLF. For him, the collaborative process was impacted by this lack of comprehension, as he mentioned one can have predefined ideas of what is going to happen once the stakeholders all start working together but the reality is different. Different interviewees brought up the question of ‘‘what I (the interviewer) meant with PLF’’, meaning PLF being a term with a broad reach. The answers were varied: data could be PLF, PLF can be methods, milking robots can be PLF, etc. This illustrates how wide the term PLF is, which in turn can reduce the comprehension of what exactly each stakeholder is referring to. Further investigation as to if the end-users can have a unified vision of PLF and its purpose could be of relevancy. One could argue that this lack of common language for actors to understand each other could negatively impact legitimacy.

6.2. Value

Value refers to the consequences of a new product category, which impacts it has. To encourage adoption, a few interviewees mentioned that one simply needs to make the benefits of a new technology clear to the farmers to encourage the adoption. This relates to the value part of the legitimization process. Benefits of PLF are a positive value for the new product category. Some interviewees mention reduced labor requirements as a positive impact of PLF, which is a way of framing the value of this product category. However, the lack of compatibility with existing infrastructure, could be a hurdle to effective adoption and, therefore, also be a negative value with the products, decreasing the legitimacy. The product then become a good idea in theory but not in practice. This is not true for all PLF technology, however. For example, Peter brought up the example of the accelerometer as a tool that is widely implemented already. When talking about PLF and whether it brings pragmatic or moral value, the interviewees presented evidence of both: PLF can both help have a more transparent traceability for products in the food chain, as well as increased animal welfare, which is of moral value, while also increasing profit for farmers, which is of pragmatic value.

In terms of value, a lack of agreement was also illustrated in the different answers as to whether artificial intelligence and sensors could capture all signs of illness or lack of welfare in livestock. Some interviewees viewed the technology as being able to better identify problems in production than humans could, while others mentioned that sensors could not comprehend animals the same way farmers with traditional knowledge are able to. If the technology can increase animal welfare, then it has value. On the other hand, as Lennart brought up, it is unknown what will happen once farmers are more used to working with the technology than without. This tipping point, when a technology is taken for granted, speaks to the legitimacy of a product category, but as expressed by the interviewees this might or might not be desirable. This brings up the question as to whether this aspect of legitimacy should be aimed for in the context of PLF.

6.3. Compatibility

Compatibility referred to the physical and social context in which a new product category will be used. For validation within the legitimacy framework, many users can signal a sort of common approval and increase legitimacy. This requires a product category to produce products used by many. But who uses PLF? And who *can* use PLF? The answer to these questions relies on who has a production that is compatible with PLF tools. The answers from the interviewees seemed to agree that mostly large-scale productions are the main target – they both are a better target for when companies need to sell many units and are also the one who might be able to afford the technology. As the interviewees said, large productions might also have a number of livestock so significant that to rely on human observation and management alone might be near impossible. However, many interviewees also brought up that small scale production can benefit from PLF, but it could be simply that the context of those small-scale productions does not allow it.

As Peter brought up, a small farm that is located outside of reach for good internet connection might want to implement PLF tools but might be restricted by the lack of infrastructure. This is related to the compatibility aspect of the legitimacy process, as PLF should be able to be implementable in farms with different conditions, which can be challenging to achieve. Small-scale farms might also be less involved with PLF due to the cost of implementation. As Gunilla pointed out, it can also be a matter of who does the investment first. This study focused on PLF being used by farmers, but as PLF can be used in different part of the food chain, and it requires a certain coherence, for example in the machinery to read electronic tags, someone needs to get the ball rolling. This compatibility aspect of legitimization thus relies on momentum – when it becomes more common than not to have PLF technology, and once it’s taken for granted, then its legitimacy increases.

6.4. Validation

Validation, which was referred to earlier as a collective evaluation of a product category, is easily perceived in the way the interviewee discusses PLF. Peter mentioned how he does not believe there is a farmer out there without an accelerometer on his cow, which indicates the widespread adoption of PLF and thus shows validation and increases legitimacy. As many interviewees expressed, farming is getting swept up in digitization just like other industries. A lot of the interviewees are part of research projects, which they mention are funded by funding agencies and bodies, which is another form of validation, as financing research shows validation. Many interviewees work with validation themselves, by actively spreading the word and encouraging collaboration between stakeholders.

6.5. Procedural justice

Procedural justice has many layers in the legitimacy framework. What feels relevant in terms of PLF is the regulations by governmental bodies for new product categories as well as a feeling of fairness in the development processes. As explained earlier, data is a part of all steps in PLF. To create PLF tools as well as to deploy and use them, data is required. This requires expertise, as expressed by Christian. One needs to be somewhat well versed in farming and farming practices to understand the data. This puts demand on high level of communication between all actors, which, as touched upon earlier, can be hard as not all of them have the ability to understand each other. Christian also brought up the need for trust between actors, especially trust between farmers and researchers. How one builds trust with farmers was not touched upon during the interviews but is of importance for data collection.

This lack of trust might cause problem when needing access to data, as Lennart mentioned how it is a problem experienced worldwide. The concept of data silos is brought up by multiple interviewees and illustrates a way in which data exists but is stored separately and does not communicate with each other. The sensitivity of handling data and sharing data is also brought up by Gunilla, who mentions how companies are keeping their eyes on the development due to their desire to own the data, which does not stand in accordance with how farmers see their data as their own. This speaks to a lack of regulation around data sharing within the Agri sector, which relates to the procedural justice of the legitimacy framework. The answers expressed by the interviewees gave the impression that we are still in a ‘wild-west’ version of data sharing. The sharing of data needs to be done in a fair and just way, possibly through law and regulations, to build trust and encourage legitimacy. Another aspect brought up during the interview that speaks to procedural justice is the absence of strong presence of farmers in development processes, which might impact how decisions about PLF regulations are perceived.

6.6. AKIS

For the collaborative process, what was explained by all interviewees aligns somewhat with the concept of AKIS. As explained earlier, AKIS refers to the development of agricultural innovation and the collaborative process of it. Most interviewees mention the fact that multiple actors are involved in the push for and the development of PLF, from research institutions to funding bodies to private companies. All interviewees specified that farmers are involved in some form or another – either as test farms where they collect data for research, or by expressing their ideas and desires for new technology to private companies. However, it is important to underline the fact that the farmers were not framed as the leaders in terms of the digitization processes as they are not necessarily the ones developing the new tools. Their role was though ascribed importance by most interviewees although none explained to exactly what extent, at what rate or how many farmers are involved in the R&D processes. This could be due to not

directly being asked directly these questions; however, there is reason to suspect that they are not necessarily at the center of this transformation. This is in line with the AKIS idea of having farmers involved in some part of agricultural innovation while recognizing that most innovation is communicated from researchers down to the farmers. In the same vein, the collaborative process of PLF involves cross-sectorial actors, such as when Max refers to SONY as a collaborator.

7. Conclusion

It is important to remember that the material for this thesis was collected from researchers within the field, and that farmers voices are absent. This does not mean that they are not important – it is evident from the collected material that farmers should have a seat at the table when it comes to discussions PLF. Looking back at the research questions for this thesis, we can reflect on the purpose served by PLF. It would be fair to say that most interviewees see the purpose being some form of optimization of production, whether it is to have higher level of animal welfare or reduced labor needs, but they all seem to have other criteria that should be fulfilled as well. As for the context of implementation, many interviewees voiced the fact that PLF could benefit different production sizes but is mainly implementable in larger production due to investment costs, infrastructure problems and overall benefits associated with the use of it. For the data, researchers require access to it, but they also must be able to understand it in some way and become expert in the subject to be able to analyze it. The access to data is limited and is still in its early stages in terms of storage, management, and legislation. Overall, precision livestock farming is a sign that we, as a society, are moving towards a digitalization of almost all industries. The idea that better decisions can be made with more data insight seems to be the primary motivation behind the push for PLF. Through my interviews, I discovered that the researchers seemed passionate about what we could accomplish with PLF, but also very reflective as to what challenges lay ahead and what impacts PLF could have on farming practices. The livelihood of farmers was also brought up on a few occasions, as it seems to be a balancing act between maintaining the traditional aspects of it and making sure it is adapted to current needs.

Precision livestock farming is hitting the mark in terms of a few legitimacy aspect, such as how many farmers are already using milking robots or accelerometers and how there is a clear signaling of the value it can bring to farmers. However, there are some improvements that can be done in terms of creating a standard for the industry and there are many aspects of the legitimacy framework that are not fully realized yet. As it is still being slowly more incorporated in farming, PLF is most probably not fully legitimized. One of the clear signs of legitimization of a product category is when it is being taken for granted by the public, and not all PLF tools are. The broadness of what PLF is also makes it hard to conclude with certainty that the product category is fully legitimized. It became clear during the research that optimization of farming practices were a clear goal of PLF, but the discussion around what an optimized farm looks like and what it means for farmers is still nebulous. What PLF can accomplish, especially in a world with a changing climate with constantly

increasing demands on farmers and animal welfare, is of significance. The field of PLF is full of potential and there are many questions that could benefit from further research. Some aspect brought up in this paper that could be of relevance for research are the impact of reliance on technology for animal welfare purposes, the state of data sharing in the Agri sector as well as assessing which production benefits most from PLF. As we move forward with the development of new PLF technology, it is important to question ourselves about this: who is it supposed to serve, in what context should it be used, and how should it be regulated?

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Appendix 1

Interview questions

- Short presentation of yourself, what you work with and why are you interested in PLF?
- What purpose do you see precision livestock farming serving in general?
- Who do you usually collaborate with when working with the development of PLF technologies?
- From what you have seen, is there a particular institution, actor or country that is leading the way in terms of PLF development?
- Who or what comes to mind when thinking about the strong voices advocating for PLF? Who are the leaders within PLF?
- Who is generally involved in the early stage of PLF R&D?
- Do you notice if the actors involved have different opinions or views regarding the purpose of PLF?
- Can you walk me through the main steps in the development phase?
- When it comes to machine learning and AI, does it matter whether the data comes from small or large productions? Does the geographical location plays a role? What kind of impact can that have?
- How do you decide what data is relevant/useable?
- Could the algorithm ultimately have an impact on how a farm operates?
- When it comes to machine learning and AI, how is the training data chosen?
- How big are training data samples usually?
- In Sweden, currently, is there wide availability of data for R&D purposes?
- Is there any way of measuring the quality or relevance of the data samples?
- Is there usually a ‘model farm’ when it comes to the target group of PLF?
- Are PLF tools currently being used by many or a select few? and should it be aimed at helping many or a select few?
- Could there be a scenario where PLF technology becomes the standard in production systems? Should it become the standard?
- What does ‘good farmer’ and ‘good farming’ means to you? What does it mean within PLF?
- Would you say PLF increases or decreases farmers autonomy?
- Can a researcher’s personal value and opinion regarding farming end up being embedded in a product being developed?
- When it comes to defining the purpose of PLF, many sources cite the desire to increase animal welfare, decrease work burden for farmers and so on. Is there an overarching definition for what this means, for example is there a specific

definition of animal welfare that is used in all development or is it up to each country's own perception of what 'animal welfare' is?

- Have you ever witnessed any differences between how a PLF technology was developed vs how it was implemented?
- Is there anything else you are thinking of that you would like to address? A question that I missed?