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The public perception of Precision Agriculture Technologies in the Netherlands

Master's Thesis

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ABSTRACT

The agricultural sector faces great sustainability challenges due to issues like soil degradation, water pollution, biodiversity loss, and climate change, hindering the achievement of Sustainable Development Goals. It is important to address these issues to balance sustainable agriculture with food security. To achieve this goal, solutions like intensifying sustainable agriculture via digital technologies (Agriculture 4.0) have emerged.

One such technology is precision agriculture. Precision Agriculture Technologies (PATs) offer significant potential for enhancing sustainable agriculture by optimizing crop yields and fertilizer use. However, their adoption faces challenges due to potential drawbacks such as high investment, which is often overlooked when assuming universal adoption. This study aims to explore public perceptions of PATs in the Netherlands, essential for aligning technology with societal needs.

This exploration was done by analyzing Dutch newspaper articles, using Klerkx et al.'s (2019) framework on agricultural digitalization for categorization. The primary finding unveiled that the public leans positively towards PATs, but not unconditionally. Analysis revealed alignment between the Dutch public and Klerkx et al.'s identified societal implications, yet unveiled additional aspects regarding trust issues on technological effectiveness that were previously unacknowledged. Moreover, it uncovered conditions necessary for successful PAT adoption and integration within the agricultural system.

These conditions guide PAT developers to incorporate public needs, enhancing technology acceptance, and aligning innovations with societal values. Public perceptions of PATs can influence policy-making, aiding policymakers in crafting inclusive technology adoption policies, thereby boosting adoption rates, addressing environmental sustainability, and food security challenges. This study pioneers understanding public views on PATs in the Netherlands, extending agricultural tech perception studies. It addresses prior misconceptions and informs precision agriculture-specific innovation models, contributing to the acceleration of technology adoption on farms.

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1. INTRODUCTION

The agricultural sector is currently not sustainable and therefore faces major challenges in achieving the Sustainability Development Goals (SDGs). Soil degradation, water pollution, biodiversity loss, rapid growing global population and climate change are examples of problems that need to be addressed (Firbank et al., 2018; Klerkx & Rose, 2020). Supporting food security while at the same time maintaining biodiversity is key to achieve these goals (Ortiz et al., 2021). The intensification of sustainable agriculture is proposed as a solution to increase productivity and minimize environmental impacts, while at the same time providing social benefits (Firbank et al., 2018; Barrett & Rose, 2020).

One way to intensify sustainable agriculture is through the implementation of digital technologies (Rijswijk et al., 2021). The transformation of agri-food systems through the implementation of digital technologies is often referred to as the fourth agricultural revolution, or Agriculture 4.0 (Zhai et al., 2020). The first agricultural revolution involves the transition from hunting and gathering to agriculture through animal domestication. The second agricultural revolution implies the industrialization of farming. The third revolution mainly focused on agricultural commercialization (Herrera & Garcia-Bertrand, 2018). The fourth revolution in the farming technology is characterized by "high-tech, radical, and potentially game-changing technologies" (Klerkx & Rose, 2020). The goal of the digitalization of agricultural systems lies in the technological optimization of value chains, food systems, and production, as well as minimizing the negative effects of agriculture on the environment (Klerkx et al., 2019; Zhang et al., 2021).

A country that experiences many challenges in reaching sustainable agriculture, as it is one of the world leaders in the agricultural sector, is the Netherlands. One such challenge is nitrogen pollution (Erisman, 2021). The Netherlands has been the European nitrogen hotspot since the 1980's, with agriculture being the dominant source, contributing 46% to nitrogen deposition (Vrolijk et al., 2020). Synthetic nitrogen fertilizer has played an important role in improving food production and keeping people all over the world adequately fed. However, in many parts of the world N fertilizer has been overused for decades. This has resulted in soil, water, and air pollution, since much of the N applied to cropland escapes the agricultural system. This disrupts aquatic and terrestrial ecosystems, which exacerbates global climate change (Zhang et al., 2013). Digital technologies are proposed to help face challenges like the nitrogen pollution (Barret & Rose, 2020).

One such a technology that can help face sustainable agriculture challenges is Precision Agriculture (PA). The goal of PA is to improve crop yields and assist management decisions, using high technology sensors and analysis tools. Additionally, large amounts of data and information are used, for example to ensure the effective management of fertilizers (Singh et al., 2020). Robotics, farm management information systems and agricultural automation are examples of digital technologies that are used in PA (Balafoutis et al., 2020; Klerkx, 2019; Rose et al., 2018). The Netherlands is, besides one of the world leaders in agriculture, also a leader in high-tech agriculture and currently intensively experimenting with Precision Agriculture Technologies (PATs) (Bellon-Maurel et al., 2023; Korotchenya, 2019).

These PATs do not only have benefits, like improving crop yields, but also hold potential drawbacks. An example of such a drawback is the costs of implementing PATs. In other words, it is not self-evident that these technologies will be accepted by the public. When it is assumed that PATs are adopted without considering the problems they might create, this may result in controversy around the technologies or even them being rejected entirely (Chivers & Rose, 2020).

In order to allow for the technology to be better aligned with the needs and concerns of the public, it is important to study the public perception of PATs. Listening to the public and tailoring the technologies to their needs can not only help to improve the reputation of specific innovations, but can also help to improve their development (Yuan et al., 2017). Moreover, the inclusion of the perception of the public in the development process is in line with insights in Science and Technologies Studies on democratization, and Responsible Research and Innovation, which involves the democratization of science and technology through the active partaking of the public (Scheibein et al., 2022). This study will focus on perceptions in the Netherlands, since especially in the Netherlands different public perceptions on PATs are likely to be present because of their intense experimentation with PATs (Bellon-Maurel et al., 2023; Korotchenya, 2019).

Klerkx et al. (2019) already conducted an extensive systematical review of social science literature on PATs using a bottom-up approach, in which they summarized themes about different social aspects of PATs into five clusters. However, in this study a more structured approach was applied, using Klerkx et al.s' framework to organize Dutch perceptions on PATs. The research question and sub questions that guided this study were:

1. What are the perceptions of the Dutch public on the main societal implications of precision agriculture technologies that should be taken into account when developing these technologies?

1.1: Which representations on precision agriculture technologies that the public mentions in the media are also mentioned in the framework of Klerkx et al. (2019) and which representations are not?

1.2: Which conditions for successful adoption of precision agriculture technologies can be derived from these representations?

This question was answered by utilizing a qualitative research design using an analysis of Dutch newspaper articles, to analyze the public perception of PATs mentioned in the public debate. Klerkx' five thematic clusters of extant social science literature on digitalization in agriculture (2019) were used as a theoretical framework and classification model during the identification of the public perception.

On a social level, this is relevant because it enables PAT developers to incorporate public needs and concerns when developing the technology. This increases the changes of the technology being accepted, and results in technologies that are better aligned with, and more responsive to, societal values. Moreover, the public perception of PATs can influence policy-making and regulation. Understanding concerns or acceptance levels can guide policymakers in formulating effective and inclusive policies for technology adoption. This would result a higher adoption rate, which in turn contributes to solving the environmental sustainability challenges and food security challenges.

Academically, this is relevant because, next to it enabling better innovations that are informed by public needs and concerns, this study is to the best of our knowledge the first study of public perception on this potentially revolutionary topic in the Netherlands. Moreover, this study contributes to studies on public perceptions of other agricultural technologies (Brossard & Nisbet, 2006; Cui & Shoemaker, 2018; Juanillo, 2001; Maris, 2001; Shanahan et al., 2001; Sparks et al., 1994). These studies all found that the public had a low level of knowledge, confusion, and wrong information about the agricultural technology in question. Moreover, they showed that the public perceived low benefits, high risks, low needs and a lot of ethical issues concerning certain agricultural technologies. In this research it was studied whether this is also the case for PATs, thereby further contributing to academic understanding of public perceptions of agricultural technologies. Moreover, insights from the public perception on PATs contribute to the creation of innovation adoption models specific to precision agriculture. Understanding the dynamics of technology adoption helps in formulating strategies to accelerate the uptake of innovative practices on farms.

2. THEORY

2.1 Literature on PATs

Multiple studies have already investigated different aspects of PATs. On the one hand, several types of benefits of PATs are discussed in the literature. For instance, PA uses technologies like GPS, drones, and satellite images. These technologies make it possible to collect various data from the land and provide farmers with other important information on all kinds of key issues, like weather forecasts, crop status and environmental changes. PATs are aimed at producing immediate benefits through environmental awareness (Yost et al., 2017). The use of PATs contributes to adequate decision-making, from a technical-productive, economic, and environmental point of view.

Another benefit of using PATs is that it allows farmers to recognize spatial and temporal variations in the production resources, which allows the application of the necessary treatments with greater precision (Aubert et al., 2012). This is more desirable than managing an entire land based on a hypothetical average condition, which may not exist anywhere in the field in the first place (Paxton et al., 2011; Rodríguez et al., 2017).

Moreover, the use of PATs can increase crop yields and reduce variability and input costs, while at the same time increasing production (Yost et al., 2017). Reducing costs can for example be done by applying fertilizer only where needed. This is done based on soil samples and analysis of yield data. Additionally, water resource management can be improved, thereby optimizing performance through automated harvesting practices (Mintert et al., 2016). PATs can help to maximize water, soil, and other resources with the aim of minimizing losses and waste, addressing the concerns about long-term use effects.

Lastly, Narra et al. (2020) state that PATs help with monitoring market dynamics more efficiently, PATs improve the planning of agricultural activities over a longer period of time and adjust the real-time strategy in case of force majeure.

On the other hand, several drawbacks of PATs can be found in the literature, of which a lack of knowledge from farmers about the use of PATs is one of the most important ones. Examples of lack of knowledge are that the farmer may have a tendency to invest in other technologies in the assumption that it would matter more than precision agriculture, which might not be true, and that it is hard to adequately select the right digital solutions for the needs of the farmer (Higgins et al., 2017; Schimmelpfennig and Ebel, 2011). The complexity of the new technologies used in precision agriculture implies a greater degree of learning skills for its proper adoption and management, which differs from person to person and thus may affect appropriate implementation (Orozco & Ramírez, 2016; Pathak et al., 2019). There are multiple technological solutions on the market that fulfill different functions and can be combined with one another. However, farmers need to have quite some knowledge to correctly select the right combinations from the available IT (Higgins et al., 2017).

Another drawback of PATs, especially for small-scale level farmers, is that some technologies require a significant investment (Reichardt & Jürgens, 2009; Schimmelpfennig and Ebel, 2011). In general, the main motive for the adoption of PATs appears to be increased profit. However, the costs of PATs may outweigh the benefits, since the investment required to implement a PAT is often significant and a long-term investment (Batte & Arnold, 2003; Pathak et al., 2019).

At the small-scale level, this investment risk is aggravated by four other constraints of PATs: small land size, technology-related difficulties, lack of supporting policy and lack of professional support. Small land can be a constraint, since most PATs are being developed for larger lands. Technology related difficulties often have to do with some small-scale farmers not having the knowledge or education to deploy PATs, since small scale farmers often were taught how to farm by an older generation. Lack of supporting policy refers to there not being adequate regulations, policy-initiated investments, or supportive policies for precision agriculture on the small-scale level. Lack of professional support means that there are fewer professional vendors, advisors, and agricultural contractor servicers for PATs in small scale agriculture (Mizik, 2022).

Moreover, most farming systems are currently conventional and market oriented. These farming systems are responsible for many of farmers' problems since they are often not sustainable. Most of the systems are based on a kind of disciplinary management style for the whole field, but to implement PATs a shift to an individualizing, informative system of sub-field control is needed. This needed shift has already created new problems in conventional farming, from concerns about rights to data, to automation, to farm consolidation (Carolan, 2017; MacDonald et al., 2013; Murray, 2018).

Other drawbacks of PATs are some social consequences of these technologies (Klerkx & Rose, 2020; Chivers & Rose, 2020). Social impacts, such as shifting power relations, workforce, the autonomy of the farmer and farmer identity may emerge after implementing PATs. Most of these social impacts relate to issues like food traceability, diets, public acceptance, safety, food security, or employment opportunities in the farming sector, but may also relate to less studied issues, like inequality (Carbonell, 2016; Chivers & Rose, 2020; Rijswijk et al., 2021; Sparrow & Howard, 2021).

Lastly, Miles (2019) states that calling the implementation of PATs the fourth agricultural revolution has the effect of normalizing the intensive, destructive industrial production of agricultural commodities, even though they are largely responsible for the social and environmental problems that the technologies are supposed to solve.

Despite of these studies that look into the benefits and drawbacks of PATs, it has, to the best of our knowledge, never been determined what the public perception of PATs in the Netherlands is. This might be a consequence of something known as "pro-innovation bias".

2.2 Pro-innovation bias and techno-optimism

Pro-innovation bias is a concept that describes how an innovation's rapid diffusion and adoption is needed among all members of a social system with few iterations to the innovation itself. However, the diffusion and implementation of innovations to fix a certain problem, often leads to bigger socioeconomic gaps within the particular social system. This happens because the unintended consequences of the innovations create new problems (Sadras, 2020).

In the discourse surrounding Agriculture 4.0, pro-innovation bias is often discussed and mostly referred to as 'techno-optimism' (Dentzman et al., 2016). From an agricultural point of view this implies that technology developers often focus on the benefits of PATs, using a techno-optimism perspective that seems to ignore eventual drawbacks (Barrett & Rose, 2020).). As mentioned in section 1, PATs have benefits, but also potential drawbacks. Assuming that PATs are adopted without considering the drawbacks they might create, may result in controversy around the technologies or even them being rejected entirely (Chivers & Rose, 2020).

Moreover, by only using a techno-optimism frame for the development of PATs, the risk of already present societal inequalities is aggravated (Chivers & Rose, 2020). A focus on techno-optimistic solutions to help address divergent global challenges may exclude benefits or drawbacks that are not technology-based, as for instance inequality. A more multi-pronged solution could be more appropriate in these situations (Klerkx & Rose, 2020).

PATs certainly have the potential to be of great importance in solving agricultural global challenges. However, to prevent techno-optimism it has been claimed that, in order to reach effective adoption, the public perception is crucial input for the development process of innovations (Barret & Rose, 2020; Klerkx et al., 2018; Lazzaro et al., 2018, Vecchio, 2022). Listening to the public and tailoring the technologies to their needs can not only help to improve the development of these particular innovations, but can also help to improve the reputation of specific innovations (Yuan et al., 2017). It increases the changes of the technology to be accepted, and results in technologies that are better aligned to societal values (Chivers & Rose, 2020). Therefore, in this research the public perception on PATs of the Dutch public is identified and classified.

2.3 Klerkx et al.s' thematic clusters of extant social science literature on digitalization in agriculture

A common way to study public perceptions via newspapers, is to use grounded theory in combination with open coding (Hu et al., 2023; Knopp, 2017; Mustonen-Ollila et al., 2020; Zhang et al., 2022). In such approaches, the public needs and concerns are identified from the bottom up, without any prior theoretical framework to organize these. However, in this study a more structured approach is used by applying a framework by Klerkx et al. (2019). Klerkx et al. systematically reviewed social science literature on PATs. They found that literature has covered different themes involving different societal aspects of PATs. They summarized these themes in five clusters. The five clusters are: 1) Adoption, uses and adaptation of digital technologies on farms; 2) Effects of digitalization on farmer identity, farmer skills, and farm work; 3) Power, ownership, privacy and ethics in digitalizing agricultural production systems and value chains; 4) Digitalization and agricultural knowledge and innovation systems (AKIS); and 5) Economics and management of digitalized agricultural production systems and value chains.

These clusters helped to categorize and structure the public perception of PATs and discover what the public perception is of these different types of societal implications that have already been identified in social science literature. Does the public identify the same societal implications – i.e.. does the public think these implications are important or not? And if so, does the public think these implications are problematic or beneficial?

In addition, the study remained open to the possibility that some public perceptions of PATs do not fit in any of the societal implications that have been identified in the social science literature. Coding was done in such a way that possible other themes, beyond the five from Klerkx, were also allowed to emerge. A summary of the five clusters is given below (Table 1).

2.3.1 Adoption, uses and adaptation of digital technologies on farms

In the cluster of adoption, uses, and adaptation of digital technologies on farms, perceptions regarding PAT adoption on farms are placed. These are perceptions are on both behavioral and economic aspects. Additionally, perceptions regarding the use of PATs and how it influences farming practices and post-adoption adaptation processes are placed in this cluster.

2.3.2 Effects of digitalization on farmer identity, farmer skills, and farm work

In the cluster of effects of digitalization on farmer identity, farmer skills, and farm work, perceptions regarding the method of farming are placed, since the use of PATs requires different knowledge, skills, and labor management of farmers. Additionally, topics on changes in what it means to be a farmer, its impact on the cultural fabric of rural areas and the identity of farmers belong here, for example that farming culture can change from using a 'hands-on' and experience-driven management style to a data-driven approach.

Furthermore, perceptions on the influence of digitalization on farmers' autonomy, for instance farmers becoming 'data laborers', and how the adoption of PATs might affect gender identities on farms belong within this cluster.

In addition, this cluster holds issues that have to do with how digitalization might displace or deskill farmers and their employees and how it might discriminate against or exclude those who are not digitally literate. This might for example affect marginalized groups, like migrants.

Lastly, practical issues of human-robot interaction, such as health and safety and ergonomics, belong within this cluster.

2.3.3 Power, ownership, privacy, and ethics in digitalizing agricultural production systems and value chains

In the cluster of effects of power, ownership, privacy, and ethics in digitalizing agricultural production systems and value chains, belong perceptions regarding the political ecologies and political economies of digital agriculture. Core issues include issues of data ownership, power, privacy, inclusion, and exclusion, and how it is ethically dealt with these issues. Within this theme, the lens of corporate structures in relation to production systems and supply chains is used. Other important perceptions relate to institutions, rules and power relations that govern these structures.

Moreover, a theme in this cluster looks how different actors are affected by digitalization and what reactions or resistances emerge, and how ethical problems, such as those around data ownership and privacy, arise and are addressed.

Other important perceptions within this theme have to do with interventions to address the digital divide produced by rapid, unregulated technological change, as well as the power imbalances that could hinder the integration of societal issues and how risks, for example cyber-attacks, can destabilize digitalized precision agriculture systems.

Additionally, also issues affecting animals belong in this theme. An example of this can be seen in the adoption of robotic milking technologies, where it has been shown that this involves a diverse range of factors, and thus diverse outcomes for animals, humans, and the environment. This has led to philosophical and ethical perspectives, in which animal autonomy and human-animal relationships of farms have been affected by ethical challenges.

2.3.4 Digitalization and agricultural knowledge and innovation systems (AKIS)

In the cluster of effects of digitalization and agriculture knowledge and innovation systems (AKIS), belong perceptions on the facilitation of digitalization by structures that support innovations, for example through big data analysis incorporation. Moreover, perceptions on the shaping of AKIS for Precision Agriculture by a diversity of existing and new actors in these systems belongs here. For example, service companies, high-tech companies, and multinational companies producing agricultural equipment, such as automated milking machines and self-driving tractors.

Another theme within this cluster is focused on the opinions of learning networks to facilitate agricultural innovation. For instance, how social media and online platforms enable global and local information sharing and peer learning and what the consequences of this are.

A last theme looks at opinions about digital decision support systems and engagement of advisors with farmers to connect famers knowledge systems to digital knowledge systems.

2.3.5 Economics and management of digitalized agricultural production systems and value chains

In the cluster of effects of economics and management of digitalized agricultural production systems and value chains, belong effects of business models, investment decisions, effects on productivity, potential economic impacts of big data services and analysis and digitalized supply chains, the economic impact of PATs on markets, and the use patterns of information.

Table 1: The five clusters of Klerkx et al. (2019) on social aspects of digitalization of agriculture.

Cluster	**Perceptions regarding**
1. Adoption, uses and adaptation of digital technologies on farms	- Behavioral and economical aspects on adoption, uses and adaption - Influences of using PATs - Post-adoption adaption processes
2. Effects of digitalization on farmer identity, farmer skills, and farm work	- Farmer identity - Farmer skills - Farm work - Method of farming - Knowledge - Skills

	- Labor management - Impacts on cultural fabric or rural areas - Human-robot interaction (health, safety, etc.)
3. Power, ownership, privacy and ethics in digitalizing agricultural production systems and value chains	- Data ownership - Power - Privacy - Inclusion and exclusion - Corporate issues - Supply chains - Institutions and rules - Digital divide - Risks - Issues affecting animals
4. Digitalization and agricultural knowledge and innovation systems (AKIS)	- Structures that support innovation systems - Shaping of AKIS - Learning networks - Information sharing - Peer learning - Social media and online platforms - Local information sharing - Global information sharing - Decision support systems - Engagement of advisors - Connecting farmers knowledge to digital knowledge systems
5. Economics and management of digitalized agricultural production systems and value chains	- Business models - Investment decisions - Effects on productivity - Potential economic impacts - Impact on markets - Impact on use patterns of information

3. METHODS

The public perception of a technology can be studied using different methods, including, for example surveys, public workshops, or qualitative interviews. Newspaper analysis is perhaps the most often used method to study public perceptions (Hoffman & Slater, 2007; Schwartz, 1984). This method was also used in this study.

Newspaper analyses are highly suitable to study the public perception for different reasons (Hoffman & Slater, 2007; Schwartz, 1996). Firstly, newspapers embody the opinion of different social groups. They are a channel for discussions that take place within a democracy. Some researchers have argued that perceptions expressed in newspapers serve as "a place where democracy blossoms because regular citizens are allowed a voice of their own" (Wahl-Jorgensen, 2004). Secondly, newspapers are generally not limited by a specialized topic and therefore contain all kinds of perceptions of large numbers of the public. Lastly, because of the limited space in newspapers, writers have to focus on things that are most valuable. Therefore, writers have to transform their ideas succinctly and clearly, in order to correctly convey their message. This is in contrast to, for example, interviews where the perception might be expressed in a less succinct and clear way.

However, newspaper analysis also has its limitations, for example that most of the time it involves some level of subjective interpretation. This might affect the reliability and validity of the results and conclusions. However, the method is still very suitable, as is evidenced by its wide usage in public perception studies (Macnamara, 2005).

3.1 Data Collection

This study used newspaper articles as unit of analysis. The articles are collected from the NexisUni database. NexisUni is a platform that holds complete texts of every national and international article. In this study only Dutch newspapers were used since this study focused on the Dutch public opinion. To make sure the complete picture of discourse happening within this subject is represented, no distinctions have been made in the publishers or sources of the newspapers. The search string was as broad as possible, while at the same time yielding a realistic amount of data. This resulted in the following search string: "precisie landbouw OR precisielandbouw OR digitalisering van landbouw AND technologie". After filtering on only 'newspapers' and grouping the double documents, 293 documents were left. The timespan of the articles reaches from 1997 to 2023, which means all existing articles were included.

3.2 Data Analysis

The collected news articles were coded using Excel. The approach that was used for coding the articles is abductive coding, which is a combination of inductive and deductive coding. This means that part of the coding tree was pre-determined by Klerkx' framework, explained in section 2.3, but the formation of codes was done during the coding process (Bryman, 2016). This approach made it possible to iterate between the theory, data, and emerging patterns to create a coding tree.

To create the coding tree with which the coding process was started, Klerkx' themes were written down in excel, for example "Adoption, uses and digital technologies on farms". Different representations of PATs that were found in the articles were classified through the perspective of the five thematic clusters to see which themes were represented in the texts. When a representation was found, the quote was copied and placed under the corresponding theme in the coding tree, including who the speaker is, the year of publication and the name of the publisher. Additionally, a code to describe the quote was written down next to it. These codes became more advanced through the study. Lastly, it was written down whether the representation was positive, negative, or neutral, and whether it was based on the technology itself or based on the agricultural system (see Appendix A**Fout! Verwijzingsbron niet gevonden.**).

After all articles were coded, the tree was checked for patterns, for example in the codes themselves, publishers, or years of publication. Based on this information, conclusions were drawn about how PATs are being portrayed in newspapers, what the public perception of PATs is and what conditions are that PATs or the agricultural system should meet to enable successful adoption.

3.3 Reliability

To increase reliability of this study, the sources of data (NexisUni), timeframe, and search string used are given. With this information it can be made sure that this research is repeatable under the same conditions, resulting in the same data set of articles. However, a potential flaw can be found in the coding process. This study was performed by only one researcher, which makes it hard to check for inter-coder reliability. To encounter this flaw, pieces of data were coded by fellow students to check for other interpretations. When the coded pieces matched, it would be stated that the reliability of the coding process is high. Per contra, when they interpreted the pieces of text to belong to different codes, discussions were held in order to come to an agreement.

3.4 Validity

In order to ensure the validity of this study, the four different concepts important for validity are discussed below.

Representativeness: To ensure the data was representative for the field of study, it was important to define boundaries of the research and find sources that fit them. This study used all available Dutch news articles, covering different actors and all possible critical moments on the topic of PATs. Therefore, this data is representative.

Temporal consistency: The data sources that were used were consistent with the research question. According to Miörner (2022), when a field with emerging developments, like precision agriculture, is studied, the data coverage of the research should grow and vary as time passes. With the mentioned search string, this is the case. The variation in coverage of the data over time can translate in critical moments, meaning they are useful to include in this research.

Homogeneity: Concepts may have been framed differently in scientific articles versus newspapers. It is important to acknowledge this and the problems this may bring. This difference in concept framing has been taken into account in the development of the search string.

4. RESULTS

4.1 Overview of findings

In total 296 articles were identified. Out of these, exactly 100 articles included one or more representations of perceptions of PATs. The articles not used often only very shortly mentioned PATs as an example without any further information, which made it impossible to analyze any representations of PATs. For example, an article on the installation of a 5G network in Groningen mentioned PATs in the sentence "This will change with 5G, making things like precision agriculture possible". While it mentions PATs, it does not include a perception regarding the technology. The 100 articles that were used are all from between 1997 and 2023. The number of articles is increasing over time, with two peaks in the time periods 2016 until 2017 and 2019 until 2021.

The remaining articles were coded for distinct representations of PATs, resulting in 384 coded statements that represent perceptions on PATs. These representations were then categorized into the 5 clusters of Klerkx et al.'s framework as explained in section 3.2. In addition, a sixth cluster emerged to encompass several representations of PATs that did not fit in one Klerkx et al.'s clusters.

A total of 54 distinct representations of PATs emerged from the analysis, with three being notably more prevalent. The most frequent representation highlighted that PATs offer environmental benefits compared to conventional farming. This representation appeared 41 times out of 384 instances (Figure 1). The second common representation suggested that using PATs facilitates cost savings in areas such as water and fertilizers. This representation was found 31 times. The third most common representation indicated that using PATs provides farm work advantages, like making farm work more efficient or easier. This representation was found 30 times.

Among these representations, a clear difference in positive and negative representations emerged (53% vs. 47%). The most common positive representations mirror those mentioned earlier: how PATs are better for the environment, help reduce costs and have farm work advantages. Controversially, the most common negative representations revolve around investment problems (like PATs being too expensive), trust issues on the usefulness of PATs (whether they do what they claim to do) and the need for change in farmer thinking (because of a different way of farming).

These positive and negative representations translate into conditions: essential qualities or criteria that PATs or the agricultural system must possess for successful adoption. For instance, in case of conditions that can be extracted from positive representations, figure 1 shows that, the most common positive representation is that PATs are better for the environment (Figure 1). Put differently, this means the PATs are represented in a positive light *because* they contribute to the environment. One can thus derive from this that PATs are perceived in a positive light by the public under the condition that PATs indeed offer an environmental advantage compared to conventional farming.

As an example of a condition extracted from a negative representation, figure 1 shows that the most common negative representation is that the public perceives investment problems for PATs (Figure 1). This means that the PATs are represented in a negative light *because* they are, for example, too expensive. One can thus derive from this that PATs are perceived in a positive light by the public, when they are under the condition that they are less expensive. These and more conditions will be discussed in more depth in the later sections.

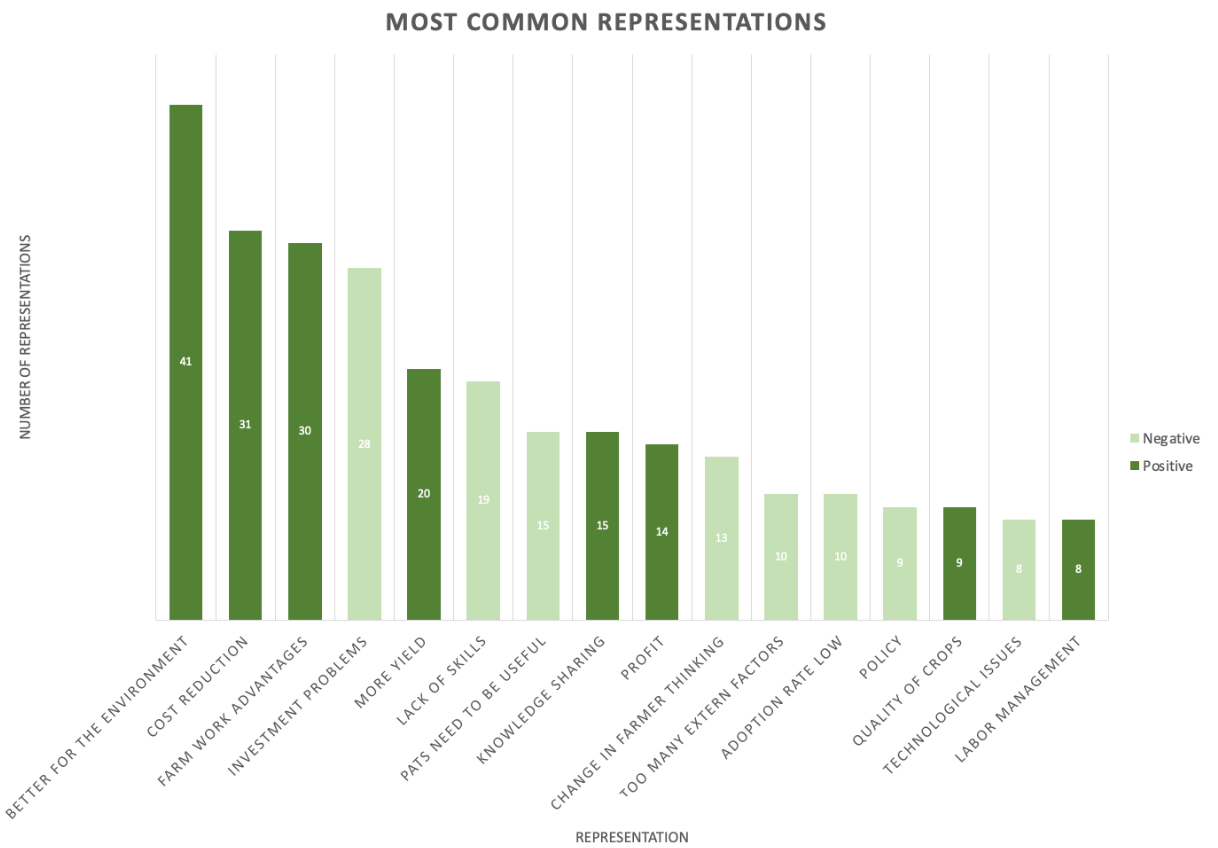

Figure 1: Top 15 most common representations and whether they are positive or negative.

A noteworthy distinction found in the data is the categorization of positive and negative representations into either technology-based or system-based aspects. This distinction is intriguing as it helps distinguish representations that solely pertain to the technology itself and those that relate to the system relations from the agricultural system PATs are located in. With this information it becomes clearer whether it is mostly the technology itself that needs improvement, or whether it is the system that needs to be changed, and which actors can help solve these issues.

From all representations combined, out of the 202 positive representations, 175 are system-based and 20 are system-based (87% vs 10%) (Table 2). This ratio shows that when the public represented in the media is positive about PATs, they are mainly positive about the technologies themselves, and not so much about the agricultural system in which PATs exist. Out of the 181 negative representations, 103 are technology-based and 69 are system-based (57% vs. 38%). Here, the actors represented in the media who are negative about PATs are both mentioning PATs themselves and the system.

The next section delves into the most common representations within all six clusters using the information from table 2 (Table 2). It will be explained whether they are technology-based, or system-based and which conditions can be derived from this.

Table 2: Number of representations per cluster with their polarity and whether they are technology-based or system-based.

Number of representations per **cluster**	Polarity **Positive**	**Negative**	**Not clear**	**Total**
1 Adoption, uses and adaptation of digital technologies on farms	**85**	**46**		**131**
Technology	77	29		106
Not clear	6	8		14
System	2	9		11
2 Effects of digitalization on farmer identity, farmer skills, and farm work	**46**	**39**		**85**
Technology	42	6		48
System	3	32		35
Not clear	1	1		2
3 Power, ownership, privacy and ethics in digitalizing agricultural production systems and value chains	**6**	**29**	**1**	**36**
Technology	6	14		20
System		15		15
Not clear			1	1
4 Digitalization and agricultural knowledge and innovation systems (AKIS)	**16**	**7**		**23**
System	15	5		20
Technology	1	2		3
5 Economics and management of digitalized agricultural production systems and value chains	**49**	**41**		**90**

Technology	49	33		82
System		8		8
6 Technological efficacy		**19**		**<u>19</u>**
Technology		19		19
Total	**202**	**181**	**1**	**384**

4.2 Clusters

The positive and negative representations were categorized into the five thematic clusters following Klerkx et al.'s framework. These clusters were: 1) Adoption, uses and adaptation of digital technologies on farms; 2) Effects of digitalization on farmer identity, farmer skills, and farm work; 3) Power, ownership, privacy and ethics in digitalizing agricultural production systems and value chains; 4) Digitalization and agricultural knowledge and innovation systems (AKIS); and 5) Economics and management of digitalized agricultural production systems and value chains.

Moreover, a sixth cluster was created for representations that did not match with one of the other five clusters. During the analysis of all representations within this cluster, a distinct pattern emerged, showing the recurring topic of "technological efficacy". This surrounds the topic of one's believe that a PAT will not successfully perform its task. It includes representations on trust issues, like not believing the technology works and not believing it is useful. This results in farmers not (yet) wanting to adopt PATs. The representation of lack of usefulness of PATs turned out to be the second most common negative representation (Figure 1).

In table 2 can be seen that cluster 1 is the biggest cluster, followed by cluster 5 and cluster 2 (Table 2). Then there is a big gap to cluster 3, cluster 4 and lastly cluster 6. The next sections will dive deeper into the six clusters, looking at which conditions are important to the public per cluster.

4.2.1 Cluster 1: Adoption, uses and adaptation of digital technologies on farms

4.2.1.1 Representations

The first cluster, focused on the adoption and utilization of digital technologies on farms, includes 131 representations out of the total 384, marking the largest share within this study. This cluster delved into behavioral aspects associated with adoption, usage, and adaptation, along with the influences surrounding the implementation of PATs. Over half of these representations leaned positively, accounting for 65% positive and 35% negative representations. This ratio, showing a slightly greater difference between positive and negative representations compared to the overall clusters' combination (54% positive versus 46% negative), suggests that the media generally portrays PATs positively, but that this is not unconditional. Within this cluster, the majority of both positive and negative representations were technology-based (91% and 63%, respectively). This highlights that within this first cluster, conditions can be extracted that are qualities the technology needs to have to put the PATs in a good light, which in turn will enable successful adoption.

A thing that stands out in this cluster is that there are 19 different representations, which is quite a lot (Figure 2). Half of these were only mentioned once or twice. The representations show that the PATs bring benefits like increasing the quantity and quality of crops, but at the same time farmers still struggle with technological issues. Furthermore, there are representations that contradict each other. For example, it is mentioned that PATs are user friendly almost the same number of times as it is mentioned that they are not user friendly. The same goes for representations about low adoption rates and high adoption rates. This large number of representations that sometimes contradict each other shows that the public perception is still quite scattered within the topic of the adoption and use of digital technologies on farms. The thing that the public seems to agree on is that PATs need to be good for the environment and need to increase the quantity of their crops.

4.2.1.2 Conditions

The most found representation revolves around the positive impact of PATs on the environment, particularly in reducing emissions. This representation emerged 41 times (31%). It is a positive, technology-based representation. This means that when PATs were portrayed in a positive way in the media, it was often because of their impact on the environment. Actors discussing PATs in these articles state that *"it is clear that the environment can reap benefits in the form of, for example, a better distribution of nitrogen and a reduced consumption of crop protection products"*. A developer agrees with this and explains that *"precision fertilization increases the efficiency of nutrient use and facilitates fertilizer replacement"* reducing pressure on the environment. This representation shows that the public finds it important that PATs help to reduce emissions and the pressure on the environment. Therefore, the condition that is extracted from this representation is that PATs need to be good for the environment.

The second most common representation in the first cluster is that PATs help in producing more yield. For example, one scientist noted that *"this 'precision agriculture' increases the yield of the land. The potato yield per hectare has increased by four to five percent*" and one government official stated with great certainty that *"technology can increase harvests without requiring more inputs in the form of land, labor or capital."* This representation emerged 20 times (15%). This is also a positive, technology-based representation. It shows that to the public it is important that PATs produce more yield than 'normal farming' would. Therefore, the extracted condition is that PATs should clearly increase the quantity of crops.

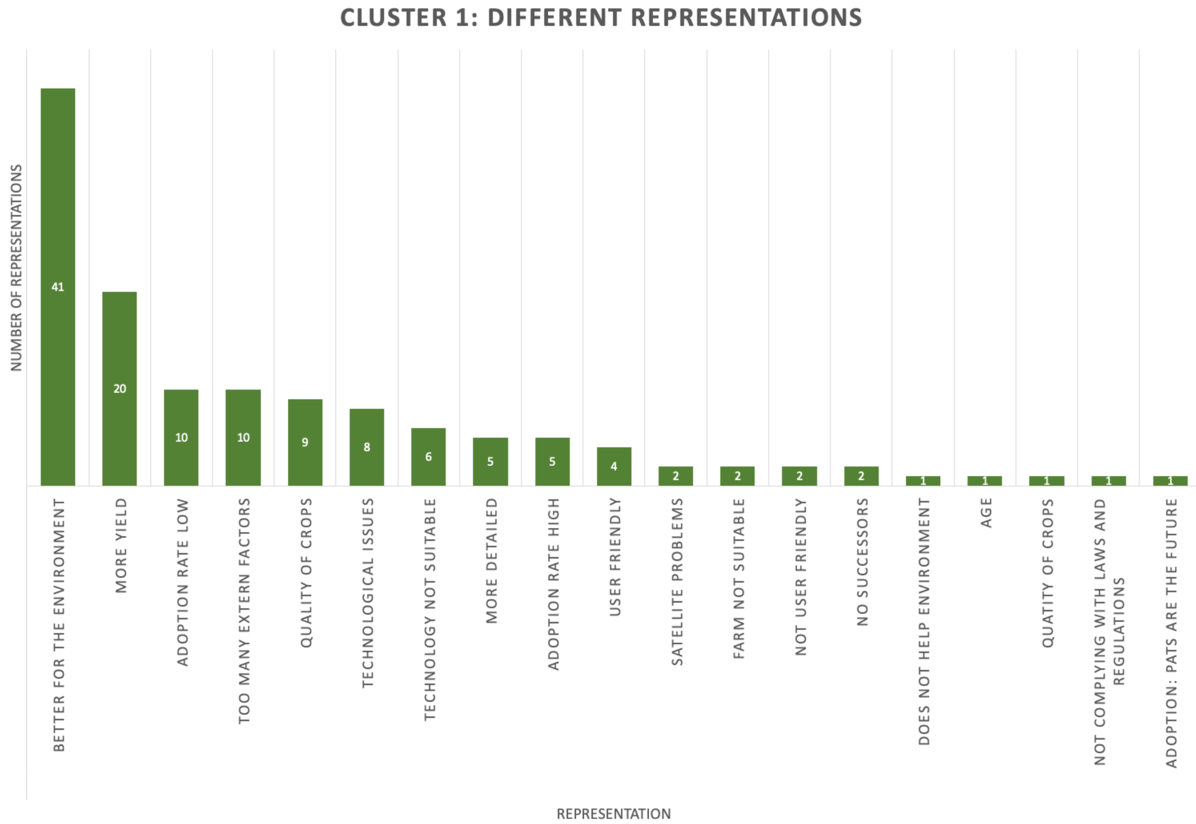

Figure 2: Different types of representations in cluster 1.

4.2.2 Cluster 2: Effects of digitalization on farmer identity, farmer skills, and farm work

4.2.2.1 Representations

With 85 out of 384 representations, the second cluster on the effects of digitalization on farmer identity, skills and farm work was the third most common cluster. This cluster included topics like skills, labor management and methods of farming. The number of positive and negative representations were almost equal, 54% and 46%. Most positive representations were technology-based (91%) and most negative representations were system-based (82%), which means in this cluster there are a lot more negative, system-based representations then in cluster 1. This indicates that within this second cluster, the conditions that are extracted below will not only be qualities that the technology needs to have, but also things that need to change within the agricultural system in which PATs exist at this moment.

9 different kinds of representations that belonged in this cluster emerged, which is half as many as in cluster 1 (Figure 3). Again, a few of these contradict each other. For example, the public does not seem to agree on whether farmer thinking and farmer identity need to change when adopting PATs. A

researcher explains this problem as that *“it is difficult for a professional to outsource work to sensors. This means you admit that a sensor is better. That's a barrier you have to cross. Some farmers have more trouble doing this than others”*. Moreover, farm work advantages are mentioned quite a lot, but at the other hand it is also mentioned, mostly by farmers, that using PATs is time consuming, which is not really an advantage. This smaller number of representations that contradict each other a lot, show that there is a debate going on in the media on these two topics of what it means to be a farmer and of what farm work is or what it should be like. The only thing that the public seems to agree on is that using PATs benefits certain tasks on a farm, but at the same time the farmers lack the skills to perform the newly created technological tasks that come with it. These tasks and skills will be discussed below.

4.2.2.2 Conditions

The most frequently encountered representation that belongs in this cluster revolve around farm work advantages. This positive, technology-based representation appears 30 times (35%). This makes it the third most common representation found in this study, which indicates that the public finds this a very important quality. There are multiple kinds of farm work advantages, for example, a farmer states that *“pest control and fertilization* can be done in the same trip. This way you can achieve maximum results with minimal input”, illustrating how PATs make farm work more efficient. Moreover, a scientist explains how a farmer “has a row of lights linked to the GPS receiver in front of him that indicate exactly then he is in the right position or when he needs to move slightly to the left or right. This also allows him to work faster, but also eliminates waste”, making clear PATs being efficient is not only about time efficiency, but also material efficiency. A lot of manufacturers also mention that *“smart applications of smart farming strengthen farmers' knowledge and help them make the right decisions”*. There are for instance solutions for early detection of disease, application of precision techniques for fertilization, crop optimization, yield prediction and future possibilities. A farmer explains that because of these technologies they are *“constantly supported in their decisions by technological applications, which can ensure robust and resilient business operations”*. There are even farmers that claim that using PATs *“makes the work much more interesting and fun”,* because *“the boring, monotonous work is done by robots, the farmer can become a farmer again”*. This representation shows that the public finds it important that PATs help to make farm work easier, more efficient, and more interesting. Therefore, the condition that is extracted from this representation is that PATs need to have these three positive qualities.

The second most common representation in this cluster is about farmer skills and knowledge. This is also the main negative representation in this second cluster. I found this system-based representation 19 times (23%). This representation covers the issues of farmers not having the technological skills and knowledge required to deal with PATs. Something that stands out is that these problems are mainly shared by researchers and manufacturers, and not as much by the farmers themselves. This could mean that this problem is in practice not actually as big as it is made to be in the media. The issues farmers mention are mostly related to data interpretation. They refer to the data as "*a mush"* and that *"you really have to be a computer nerd to be able to make anything out of that"*, but also that *"the data is of good quality, that's not the problem"*, indicating it is not a technological issue. The issues mentioned by researchers and manufacturers relate more to the skill-based changes that are needed for a farmer to be able to work with the technology. For example, a manufacturer states that *"just having a green thumb is no longer enough. Today's entrepreneurship also requires other skills: knowledge of ICT, logistics and personnel management"* and that therefore *"at the moment many of the technologies are only for the real pioneers."* Consequently, instead of translating this system-based representation into a condition for PATs, I translate this representation into a condition for the agricultural system in which PATs are used. The condition is that there need to be opportunities for farmers to educate themselves on the technology.

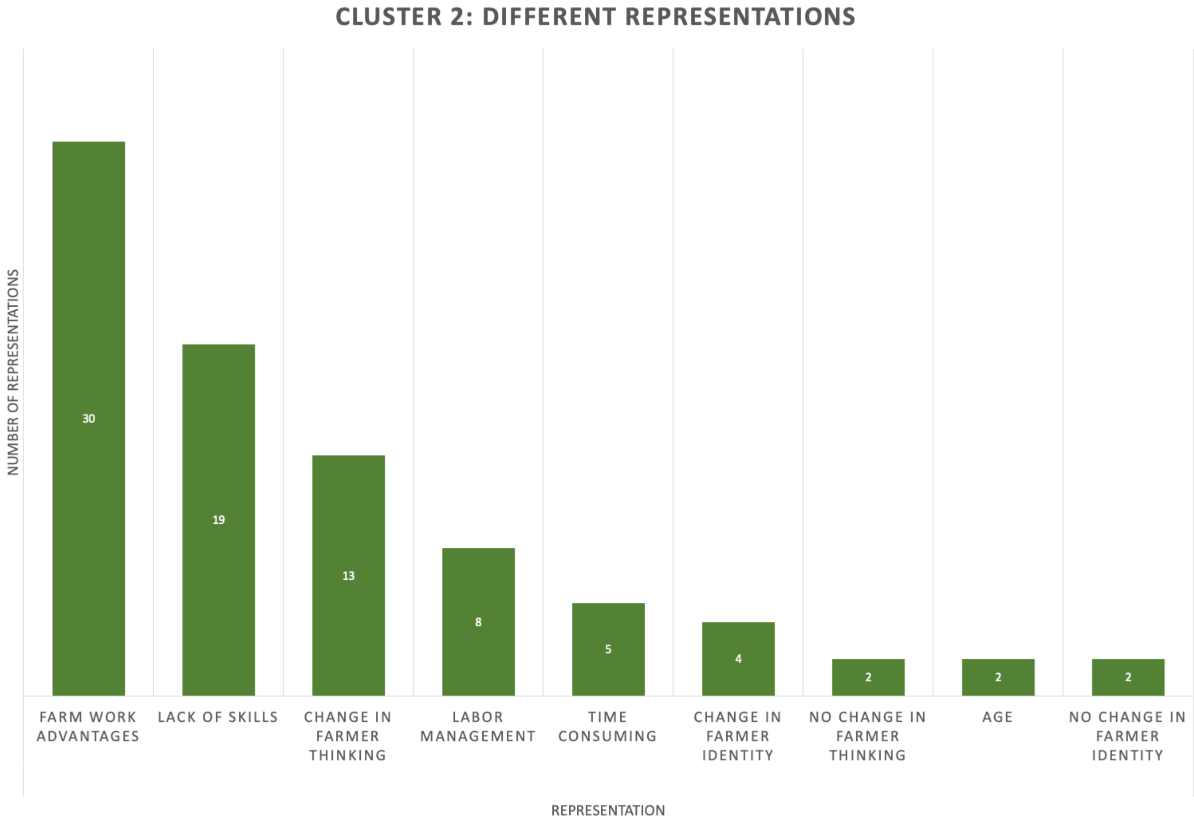

Figure 3: Different types of representations in cluster 2.

4.2.3 Cluster 3: Power, ownership, privacy and ethics in digitalizing agricultural production systems and value chains

4.2.3.1 Representations

The third cluster on power, privacy and ethics was the fourth most common one. This cluster includes 36 out of the 384 representations. It involves topics like institutions and rules, digital divide, issues affecting animals and data ownership. The biggest share of representations within this cluster is negative: 75% negative and 22% positive. This makes this cluster the foremost negative cluster. It means that there exists a negative image of power, privacy, and ethical topics of PATs in the media. Of the positive representations, 88% was technology-based. Of the negative representations, 48% was technology-based. This indicates that within this second cluster, the conditions extracted below will be both relate to the PATs themselves, as well as to the agricultural system.

There are a lot of different actors discussing this subject. However, farmers and researchers are represented most often. There are 9 different kinds of representations, of which most have to do with policy or data issues (Figure 4). This, combined with the fact that most representations are negative, shows that the public thinks negatively about how the government handles PATs and what can be done with the data. Notably, privacy is not mentioned once. Moreover, there is only one negative representation on ethics, all other mentions of ethics are positive. This is not aligned with Klerkx' research, where it is found that privacy and ethics are popular research topics.

4.2.3.2 Conditions

The representation that occurred most in this cluster is about how (lack of) policy influences farmers in the adoption process. Out of the total of 37 representations found in this cluster, this one was used 9 times (24%). This is a negative system-based representation about the circumstances surrounding PATs. A farmer explains that he *"was interested in participating at the time. I just felt limited by the regulations. That's why I put it aside."*, which shows how lack of regulations negatively influenced his decision-making process. But it is not only farmers who have this need. *"Commercial parties and researchers urgently need clear regulations"* too, as a researcher explains. An example he uses are drones, for which "*regulations are still a grey area, which does not help sell those things"*. Therefore, the condition for the agricultural system that is extracted from this representation is that the government needs to provide more and better policy, rules, and regulations for PATs, in order to support farmers who want to adopt PATs, commercial parties who want to sell PATs and researchers who want to study.

The second most common representation in this third cluster is that adopting PATs comes with data ownership issues. These kinds of data issues are mentioned 7 times (19%). This is a negative technology-based representation. A large consultancy firm argues that *"so far, suppliers and technology companies* *in particular have benefited from the farmer's data. The farmer may own the data, but it is the software suppliers and tech companies that translate the data into advice. These suppliers invest heavily in big data, unlike farmers. Farmers therefore run the risk that IBM, Google, DuPont or John Deere will soon know more about farming than they do".* A farmer agrees with this, explaining how he wants *"access to the raw data from soil scanners so that he can draw his own conclusions instead of the manufacturers doing so".* According to the consultancy firm "*it is essential that farmers understand the data and technology themselves and benefit from it. The first step is to choose a technology supplier that shares the data with other developers and gives farmers control over the use of the data".* The condition that can be subtracted here is that PATs need to share their data with other PAT developers and at the same time need to allow farmers to own and control the data they collect.

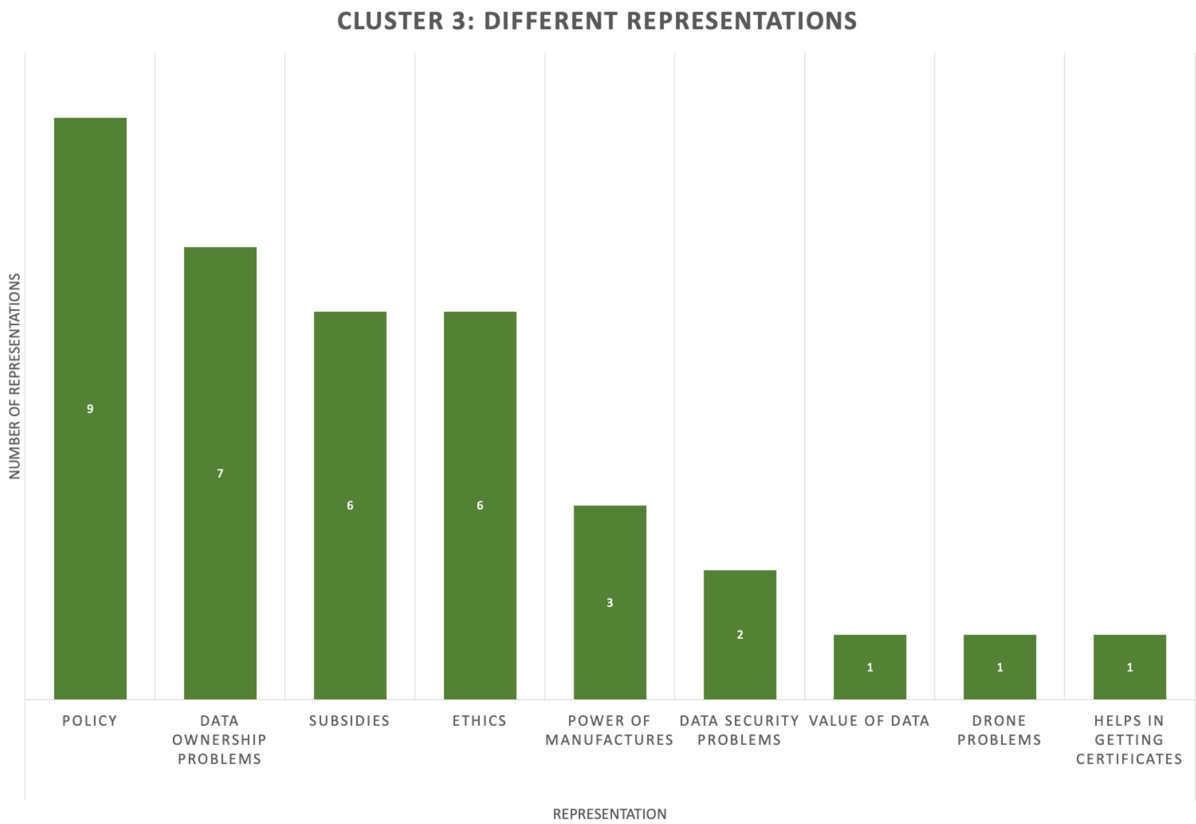

Figure 4: Different types of representations in cluster 3.

4.2.4 Cluster 4: Digitalization and agricultural knowledge and innovation systems (AKIS)

4.2.4.1 Representations

This fourth cluster on digitalization and AKIS includes 23 out of the 384 representations, which made it the least common cluster. It involved topics like information sharing, learning networks, social media, and local information sharing. There were more positive representations than negative ones (70% vs. 30%). Most positive and negative representations were non-technology based (94% and 71%), which means this small cluster is practically entirely non-technology based. This is not a surprise since it is about sharing knowledge within the system.

In this cluster there are 4 different kinds of representations, which is very few (Figure 5). Two of them are only mentioned once. They were about collaboration problems (and the need for open innovation) and supporting innovations (by high-tech firms in order to familiarize farmers with PATs). The other two contradict each other: knowledge sharing and knowledge sharing problems. However, knowledge sharing itself is mentioned almost three times as often as the problems of knowledge sharing (65% vs. 26%). These two representations are both system-based. Therefore, the conditions that are derived below will only be things that need to change within the agricultural system that exists at this moment.

4.2.4.2 Conditions

The positive representations on knowledge sharing hold a very positive public view on topics like information sharing and learning networks and are most often about de Nationale Proeftuin Precisielandbouw (NPPL), which is, as a researcher explained, *"set up to convince farmers of the added value of precision agriculture by implementing example cases of precision agriculture in practice. Farmers are selected for this every year. They are guided and supported for a year. Bottlenecks that farmers encounter are resolved as quickly as possible"*. A farmer calls NPPL *"a place where we can get knowledge and technology that will help us increase our yield and quality"*. Moreover, NPPL helps to convince farmers to adopt PATS, as becomes clear from a researcher that states that *"NPPL participants are satisfied with the effectiveness of soil moisture sensors to predict the right time for irrigation"*.

The negative representations on knowledge sharing have one thing in common: the need for more knowledge sharing. This is however never mentioned by farmers, only by researchers and authors of the articles. They argue that *"there are plenty of possibilities for the application of precision agriculture, but they are far too largely academic"* and are *"very concerned about the fact that the enormous knowledge that is being developed everywhere in all kinds of areas does not sufficiently reach the farmer"*.

These contradicting representations show that farmers are happy with the knowledge sharing options that are provided for them, but that researcher seem to think there is more knowledge that could be shared with the farmers. Knowledge that the farmer may not know exists in the first place. Therefore, the condition that can be extracted from these contradicting representations is that a way must be created to get academical knowledge to farmers in such a way they understand this information and can use it in either their decision-making process or during the application of the already adopted PATs.

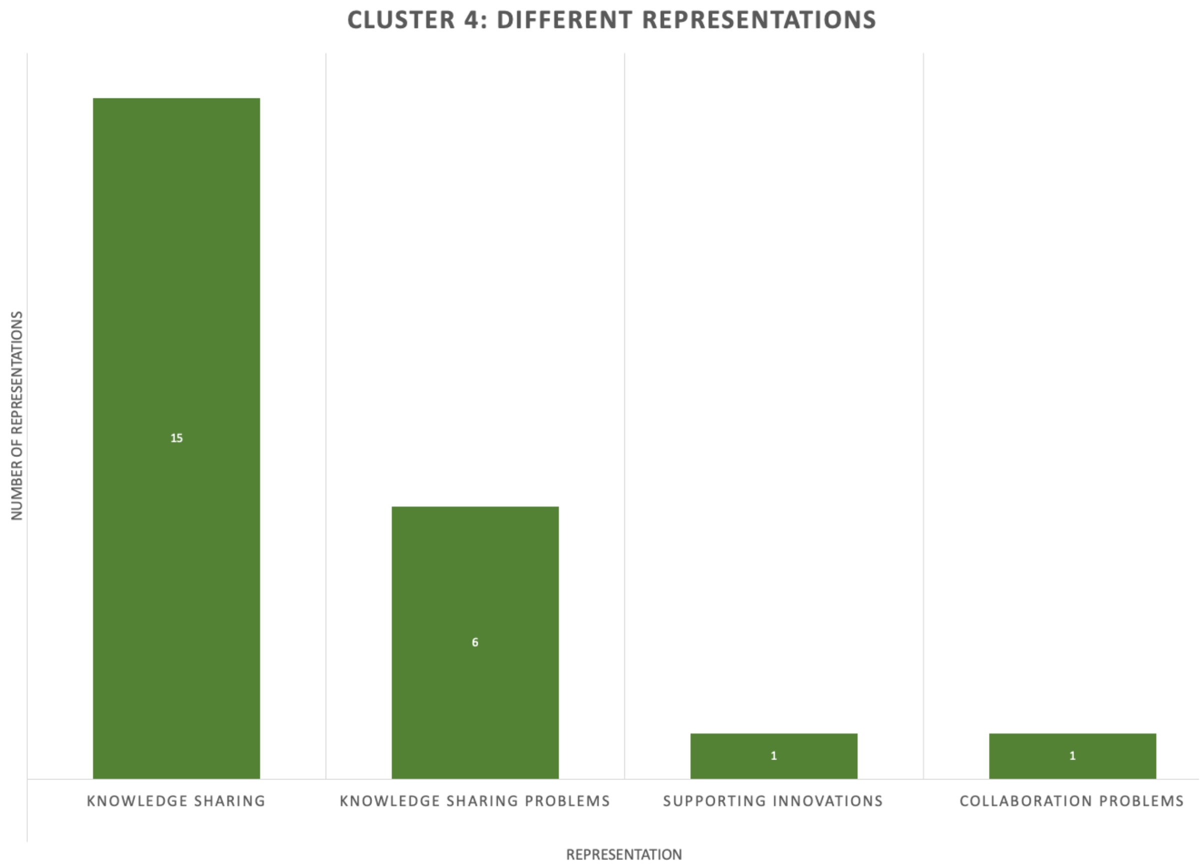

Figure 5: Different types of representations in cluster 4.

4.2.5 Cluster 5: Economics and management of digitalized agricultural production systems and value chains

4.2.5.1 Representations

The fifth cluster on economics and management was the second most common cluster. It included topics like business models, investment decisions, economic impacts, and markets. It included 90 out of the 384 representations, of which 54% was positive and 46% was negative. This means that opinions about economics and management of PATs in the media are divided. Of the positive representations, 100% was technology based and of the negative representations, 80% was technology based, which tells us that within this fifth cluster the conditions that are extracted below will both relate to the technologies themselves.

There were a lot of different actors that discussed this subject, like politicians, contractors, entrepreneurs, and consultancy firms. However, farmers and researchers were once again represented most often. There are 11 different kinds of representations, of which most have something to do with money. For instance, costs, investment, and profit (Figure 6). That money is extensively debated in the media shows that for the public money is an important topic. Moreover, there is only a handful of actors who mention management: a farmer, a politician and an environment organization talk about how revenue models and clear goals are missing. The other two mentions are from a politician and an author who argue that there are possibilities for new business models. Since farmers do not mention management as much, this might mean that farmers do not have that much trouble implementing PATs into their way of farming.

4.2.5.2 Conditions

The two representations found the most in this cluster are money related: how using PATs helps to reduce cost of for example time and materials (34%), and how there are a lot of investment problems (31%). These two representations tie in well with the almost equal percentages of positive and negative representation I mentioned above. It shows that on the one hand people who have trouble to invest in PATs look negatively at PATs, but on the other hand people who have already invested in PATs are happy about the amount of money they generate and have a more positive view of PATs.

A researcher explains that a farmer reduces costs because he *"has to irrigate less quickly to ensure the correct moisture content on his sandy soil by using sensors. Sometimes this saved a few days, allowing him to irrigate a larger part of his field with one reel"*. In other words, by using PATs he saved a lot of water, and therefore money. But it is not only water that is saved. This farmer who tells a journalist that *"during the weed control on this plot, ninety percent of crop protection products were saved. In those places it also concerns root weeds. They stay in the same place. We were able to use the map from the first year in the other cultivation the following year"* explains that he reduced the use of crop protection products (which is also better for the environment), and by reusing the weeds map, he also reduced time spend on weed control and therefore reduced labor costs. The condition that can be subtracted here is that PATs need to reduce costs of either materials or labor.

The negative representation about investment problems is, as a researcher explains, about how *"for many farmers, the expensive investments in technology often prove to be simply too great or simply go over their heads"*. He argues that *"the majority of farmers are keen on new technological possibilities, but do not have the money for them"*. A developer agrees that *"on a large company with an intensive construction plan and many employees, it is easier to make precision agriculture profitable"*. Moreover, a contractor that has already invested in PATs explains that *"you need to have enough hectares. A farmer cannot take the risk of buying an experimental machine that will stand still for most of the time"*, explaining that it is risky for farmers to make big investments like this. Farmers agree that these investments are major obstacles in the decision-making process of purchasing of PATs. One of them states that *"if you have 400 hectares, you can recoup the investment. The average farmer in the*

Netherlands has 100 hectares, which makes it difficult". The condition that can be subtracted here is that PATs should be affordable for smaller farms, and not only for bigger farm and contractors.

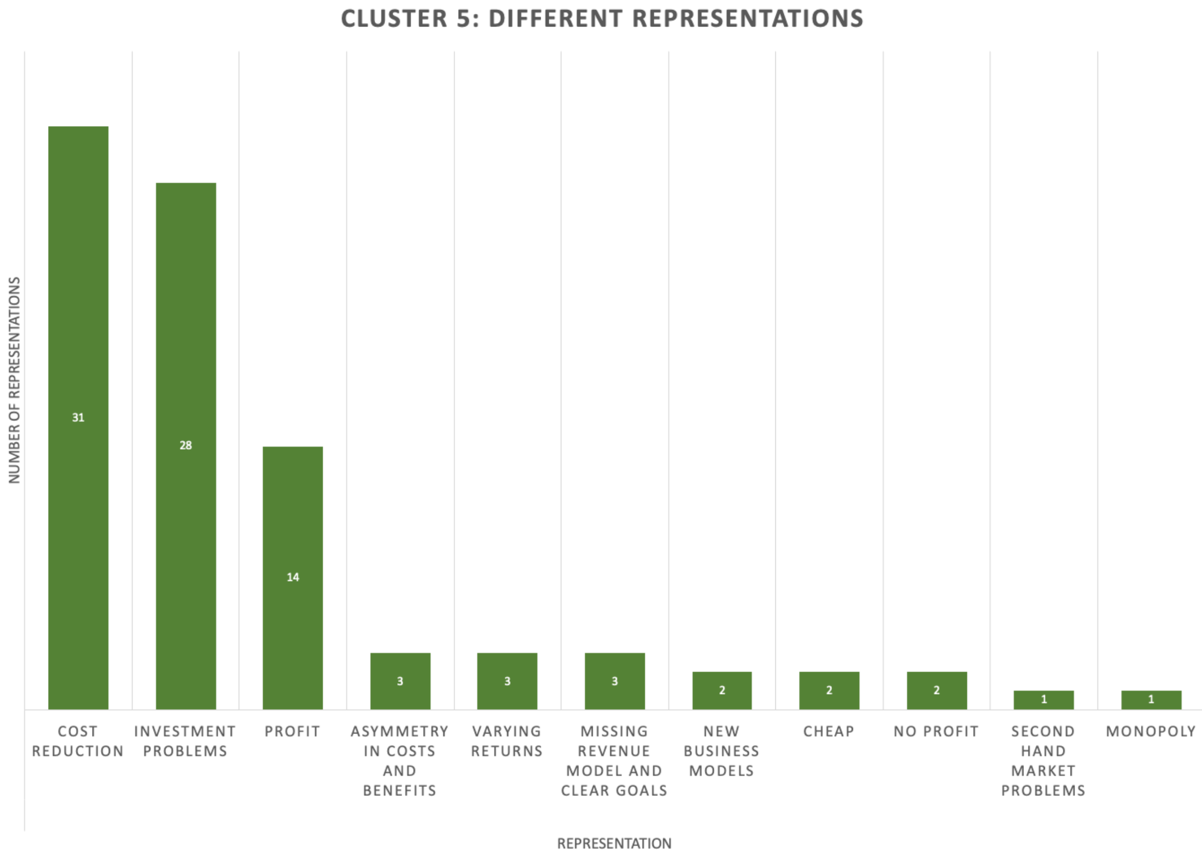

Figure 6: Different types of representations in cluster 5.

4.2.6 Cluster 6: Technological efficacy

4.2.6.1 Representations

As explained in section 4.2, a sixth cluster called 'technological efficacy' emerged, which included representations that did not fit in one of the other five clusters (Figure 7). This cluster included only representations on the believe that a PAT will not successfully perform its task. These are negative technology-based representations that all have something to do with trust issues from the farmers' side. For example, trust issues on whether the technologies do what they claim to do and trust issues on whether the farmers will be able to handle their technologies. With 19 out of 348 representations, this sixth cluster has the least representations. However, it is still a very interesting cluster, since Klerkx et al. did not come across these issues in their literature review on the digitalization of agriculture. However, these issues are heavily debated in the media and therefore seem to be a significant problem for the public.

4.2.6.2 Conditions

The representations were mostly expressed by researchers and farmers. This makes this cluster interesting too, because this contradicts what was found in the literature (even besides Klerkx et al.s' review), where no research was done about these kinds of trust issues. There was some research about farmers missing technological knowledge and them not getting the right information from the researchers and developers, and therefore not wanting to invest in PATs, but these representations are not about lack of knowledge of the farmer. They are about them simply not believing the information and promises the developers present. A researcher explains this through the example of drones: *"Use of drone data has environmental benefits, fewer crop protection products, more efficient use of water and fertilizers, and therefore in principle leads to lower costs. However, farmers are not convinced of this. There is a lack of hard figures to provide insight into the benefits for farmers and the environment"*. In other words, before the farmers will invest, PATs need to *prove* that they do what they claim to do. The promise of PATs is not taken at face value. This farmer agrees with the researcher and states that "*the added value is only proven when the technology proves its usefulness. And it has not come to that everywhere yet"*. Therefore, the last condition that can be subtracted is that PATs need to actually be useful and that their usefulness has to be *proven*.

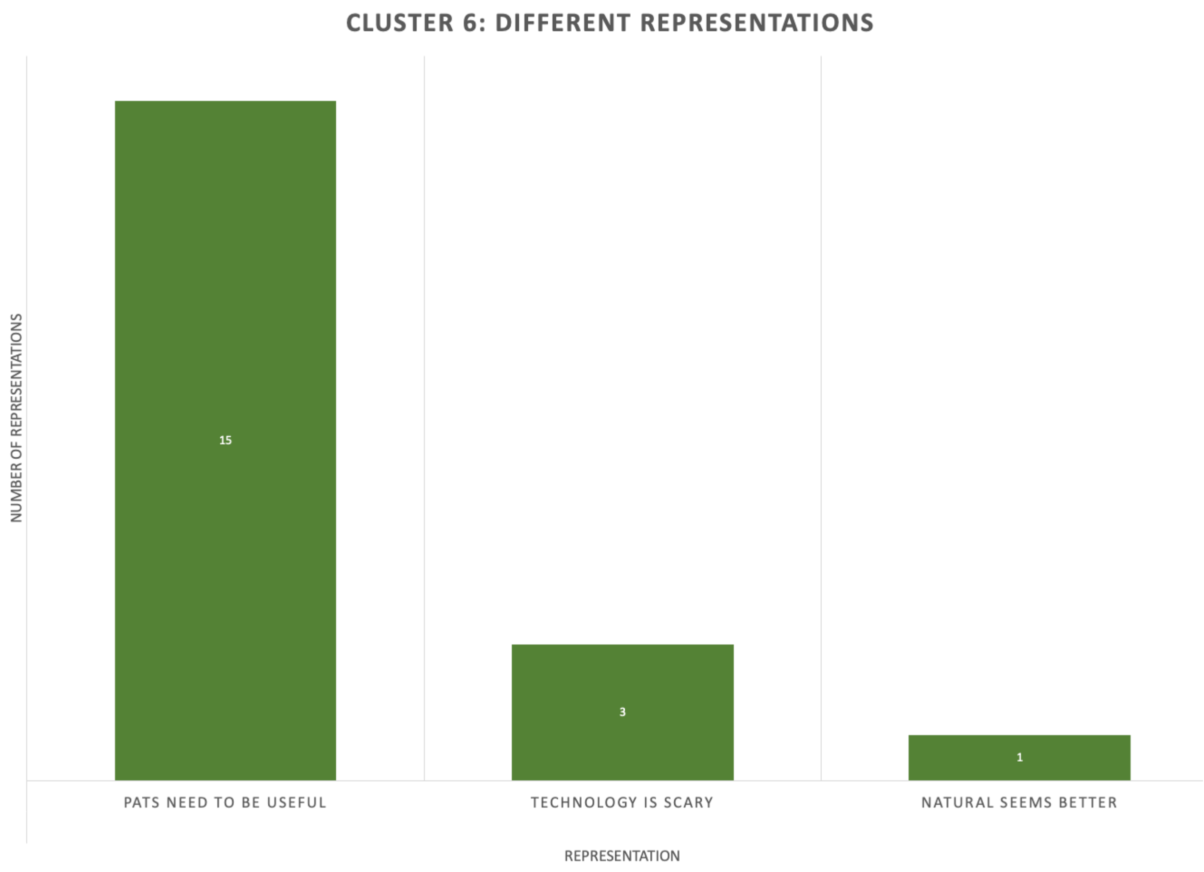

Figure 7: Different types of representations in cluster 6.

4.3 Overarching findings

From all representations combined and when taken as an indication of the public perception, it can be concluded that the public is open to purchasing and using PATs. However, effective adoption will only occur if a number of conditions are met. These conditions have been extracted from the representations that appeared most often in the media. An overview of these conditions can be found in table 3 (Table 3).

What stands out is that PATs are not discussed in isolation. Some representations are technology based, while others are about the system in which these technologies exist. Therefore, some of the extracted conditions are meant for the PATs themselves, and thus important information for the developers and researchers working on these PATs, while others are focused on the agricultural system, which means they are problems developers cannot solve. These kind conditions are important information for different actors in this system, for example government employees that work in the agricultural sector or academics that hold information about PATs that could help farmers in their decision-making process.

Table 3: Conditions for PATs and the agricultural system to allow for effective adoption of PATs.

Condition	Important for
PATs should be good for the environment	Developers
PATs should increase the quantity of crops	Developers
PATs should be adaptable to their surroundings	Developers
PATs should help to make farm work easier, more efficient, and more interesting	Developers
There should be opportunities for farmers to educate themselves on the different technologies	Government
PATs should share their data with other PAT developers	Developers
Developers should allow farmers to own and control the data they collect	Developers

Better policy, rules and regulations to support farmers, commercial parties and researchers should be provided for PATs	Government
PAT data should be shared with other developers	Developers
A way to get academical knowledge about PATs to farmers in such a way they understand this information should be created	Government and academics
PATs should reduce costs of either labor or materials	Developers
PATs should be affordable for smaller farms	Developers
PATs need to actually be useful and their usefulness has to be proven	Developers, researchers, and academics

5. CONCLUSION

Precision Agriculture Technologies are highly promising for intensifying sustainable agriculture. By the implementation of PATs, crop yields can be increased, and the use of fertilizer can be effectively managed. However, in contrast to these positive qualities, PATs also hold potential drawbacks, as for example the high investment that is sometimes needed. This means that it is not self-evident that these PATs are adopted by the users. Nonetheless, it is often assumed that PATs are adopted without considering the problems they might create. This gives rise to controversy around the technologies or even to complete rejection. This study focused on better aligning the technologies with the needs and concerns of the public, since listening to the public and tailoring the technologies to their needs helps to improve the development, reputation, and adoption rate of these innovations.

The research question guiding this study was: "*What are the perceptions of the Dutch public on the main societal implications of precision agriculture technologies that should be taken into account when developing these technologies?*". These social implications were studied by categorizing representations of PATs found in the media. These representations were used as an indication of the public perception. For the categorization of the PATs the framework of Klerkx et al. (2019) on digitalization of agriculture was used. These representations revealed that the Dutch public largely aligns with the societal implications of PATs identified by Klerkx et al. However, additional implications on the subject of technological efficacy emerged that were not previously noted by Klerkx and colleagues. Furthermore, these representations uncovered multiple conditions that PATs and the agricultural system must fulfill to facilitate successful adoption.

4.1 The perception of PATs

This study reveals that the Dutch public is equally positive and negative about adopting PATs. On the one hand, they mention positive things about, for instance, the influence of PATs on the environment, a higher quantity of crops and farm work. On the other hand, they mention negative things about topics like investment issues, usefulness of PATs and the need for change in farmer thinking.

In addition to differentiating between positive and negative representations, this study also identified a distinction between technology-based and system-based representations. The technology-based representations revolve around benefits and drawbacks of the technology itself, whereas the system-based representations include benefits and drawbacks of the agricultural system in which PATs exist.

There were more technology-based representations than there were system-based ones. For example, the representations on investment issues, usefulness of PATs, the influence of PATs on the environment, the higher quantity of crops and farm work are technology-based. They are all drawbacks and benefits of the technology itself. However, the representation on the need for change in farmer thinking is system-based. PATs cannot change this, since it is part of a bigger system. These worries of the public about the system make it clear that simply changing de technologies itself won't immediately mean that the technologies will be successfully adopted. There are changes needed in the agricultural system itself too.

The combination of the many positive and negative representations and technology-based and system-based representations shows that the public does not just simply believe all promises that are made by developers. There are needs, concerns and problems that have to be dealt with if we want successful adoption. Therefore, the conclusion of this study is that the Dutch public is willing to adopt PATs, but only if particular conditions are met. These conditions being either on the side of the technology or on the side of the system.

4.2 Conditions

The conditions are essential qualities or criteria that PATs or the agricultural system must possess for successful adoption. These conditions were derived from *both* the positive and negative representations of the Dutch public found in this study. Conditions that were derived from positive representations revolve around about already existing qualities that put PATs in a positive light. Conditions that were derived from negative representations are about missing qualities which put PATs in a negative light. When PATs or the system *would* have these qualities, it would contribute to resolving the negative perceptions on these topics.

Conditions could be derived from all social implications of PATs. However, in this study only the social implications that were mentioned most often in the media were used, since their frequency shows that these implications are most prevalent among the public. Therefore, these conditions could have more impact on successful adoption of PATs. The conditions are summarized in table 3 (Table 3: Conditions for PATs and the agricultural system to allow for effective adoption of PATs.).

6. DISCUSSION

This section discusses findings on the perception of PATs by reflecting on the framework of Klerkx et al. that was used, in order to get a broader view perspective of the results. Secondly, it will review the limitations of this study. Lastly, recommendations for further research will be given.

6.1 Results in a broader perspective

Most conditions matched the societal implications Klerkx et al. mention in their framework on digitalization of agriculture. This shows that the benefits and drawback that are discussed in the literature, also exist in practice. However, one issue that existed in practice did not show up in the literature. This is the problem of how the public feels that some PATs are not as useful as developers claim them to be., which belongs to the newly emerged cluster of technological efficacy. A lot of actors doubt the effectiveness of these proposed technologies – whether they actually do what they promise to do, and whether they are worth the investment. The technology is not accepted at face value. The public needs to be sure these PATs are useful and that they meet the conditions mentioned in table 3. And they need proof that these conditions are met. The apparent lack of attention paid by current literature to this worry of the public underscores the need for academics to further address and explore this aspect.

A second observation is that prominently discussed issues from the framework of Klerkx et al., like power, privacy and identity, are discussed less in the media. Similar to the previously mentioned observation, this further suggests a potential discrepancy between what science prioritizes and what genuinely concerns the public. It hints at the presence of a techno-optimistic frame guiding the development of PATs, emphasizing a focus that might not fully align with the public's actual priorities or concerns.

Other academical relevance is that this, to the best of our knowledge, is the first study of public perception on PATs in the Netherlands, contributes to studies on public perceptions of other agricultural technologies. As mentioned in section 2.1, these studies found that the public had a low level of knowledge, confusion, and wrong information about the agricultural technology in question. This turns out to be the case for PATs, too. Additionally, the studies showed that the public perceived low benefits, high risks, low needs, and a lot of ethical issues concerning certain agricultural technologies. Controversially, this was not found for PATs. According to the public, there are certainly benefits, but also needs for PATs. Moreover, representations on ethics were only mentioned a handful of times and generally positive. Therefore, this study is an interesting contribution to academic understanding of public perceptions of agricultural technologies.

Additionally, these insights from the public perception on PATs contribute to the creation of innovation adoption models specific to precision agriculture. The conditions can help in researching and formulating strategies that accelerate the uptake of PATs.

The derived conditions help us to better understand society. When developers would comply with these conditions, the technologies would be better aligned with the needs and concerns of the public, helping the reputation and development of PATs. This increases the changes of the technology being accepted, and results in technologies that are better aligned with, and more responsive to, societal values.

Furthermore, the conditions could help policy makers to create better ideas and plans that support farmers, researchers, academics, and developers that work on and with PATs. Examples of policy measures are ensuring that there is good communication about benefits and qualities of PATs, providing information about what PATs are tested on, sharing (positive) experiences of other fellow farmers, providing knowledge sharing platforms or gatherings, and support small farms that want to invest in PATs, for example through subsidies.

6.2 Limitations

Although considerable efforts have been made to carry out this research as systematically and academically well as possible, some limitations should be highlighted.

First, there are some limitations on the use of newspapers. Newspapers serve as one source of information about public perception, but they may not provide a comprehensive view of the entire Dutch population's attitudes and opinions on precision agriculture technologies. These newspaper articles represent only a portion of the Dutch population. Not everyone talks to journalists, and those who do may not be a representative sample of the entire demographic spectrum, including age groups, socio-economic backgrounds, or geographic regions. Additionally, newspapers do not allow for direct interaction with the audience. They provide a one-way flow of information, limiting the ability to delve deeper into nuanced perspectives or engage in a dialogue to understand diverse viewpoints. They are also subject to editorial decisions that can shape the content and focus of articles. Editors might choose stories based on their perceived relevance, newsworthiness, or alignment with the publication's agenda, potentially omitting certain viewpoints or aspects of public opinion.

Second, developers of PATs require more than just an understanding of the public perception to ensure successful adoption of PATs. The development of technology is controlled by a whole system. Therefore, other interconnected aspects concerning the adoption of PATs within the agricultural system need to be considered. An example of such an aspect is that they need to gather insights from industry experts, agricultural consultants, and research institutions. This helps developers stay updated on the latest advancements, best practices, and emerging trends within the agricultural sector. Another example is that keeping abreast of regulatory requirements and compliance standards is vital. Developers still need to ensure that their technologies align with local, national, and international regulations governing agriculture, technology, and data usage.

6.3 Recommendations for future research

The findings on the Dutch perception of PATs and the from there derived conditions to enable successful adoption of PATs lay the basis for recommendations for future research.

First, the contradicting finding of implications that were found in the literature but not or barely mentioned by the public should be studied in more dept. It would be interesting to see why topics like power, privacy and identity receive so much attention from academics and researchers but seems to be less important for the Dutch public. Additionally, the social implications in the new cluster of technological efficacy, that was not found in the literature, should be further explored.

Second, the two peaks of articles in 2016-2017 and 2019-2021 that could not be explained by the data found in this study should be further examined. Two considerable events that were mentioned a handful of times and occurred during this period are Covid-19 and the nitrogen crisis. Both these events have affected the agricultural sector (Beckman & Countryman, 2021; Stokstad, 2019). It would be very interesting to see whether these two events have any influence on the perception of PATs, and if so, what this influence is.

Third, it would be interesting to look into the perception of PATs in other countries. As mentioned, the Netherlands is a country that experiences many challenges in reaching sustainable agriculture, as it is one of the world leaders in the agricultural sector. Therefore, the Dutch public may experience different social implications than people in other parts of the world do. To see whether policy in other countries should differ from policy in the Netherlands, conditions should be studied per country.

And lastly, as explained in section 6.2, research is needed to find out what other interconnected aspects concerning PATs there are in the agricultural system. The development of PATs is driven by the whole agricultural system. By focusing on all of the different system-related aspects of PATs, future research could support the development of more sustainable, easy-to-use, and contextually relevant PATs that can be effectively integrated into the evolving and diverse agricultural system.

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8. APPENDICES

Appendix A. Empty coding scheme in Excel.

	A	B	C	D	E	F	G	H	I	J	K
1	**Article**	**Quote**	**Code**	**Cluster**	**Who is speaking**	**Date**	**Publisher**	**Positive or Negative**	**Technology or sytem based**		
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