THE APPLICATION OF DRONES IN PRECISION AGRICULTURE

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ABSTRACT,

The Association for Unmanned Vehicle Systems International stated that 80% of Unmanned Aerial Vehicles (UAVs) will be used for agricultural purposes in the near future. But how ready is the agricultural sector for drone usage? And how ready are the drones to fully function on the farm? This research aims to examine the maturity of drone usage in precision agriculture while using different dimensions and what implications there are for its development. For the research, the Space 53 UAV Readiness Quick Scan was used to measure the drone matureness on five different dimensions. These dimensions are technology, business, ethical, legal, and social. The data gained from using the Space 53 tool are discussed with an expert in precision agriculture, technology, and drones.

The results of this study show that there is still development needed when it comes to the readiness of all five dimensions. The drones themselves are ready to be used on the field; however, the environment, farmers, regulations, and the business case are not ready to fully implement and use drones for precision agriculture. To reach a more mature readiness level, drones need to be easier to implement with existing technology present on the farm and the positive effect of drones should be financially substantiated. The sector should watch out for the technology push present in the sector and focus on the values drones can add to the farmers and the precision agriculture field. This study highlights the importance of involving business, social, ethical, and legal aspects for developing new technologies.

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1. INTRODUCTION

1.1 Situation and complication

Planes and helicopters have become a big part of the current environment. But these planes do not need humans on board to be able to fly. The twenty-first century is seeing a rapid proliferation of aerial vehicles that do not have a human controller on board. These unmanned aerial vehicles (UAVs) are also called drones. Drones can be defined by using different elements, namely: the device must be heavier-than-air; the device must have the capability of sustained and reliable flight; there must be no human on board of the device; and there must be a sufficient degree of control to enable the performance of useful functions (Clarke, 2014).

Drone techniques are not only used for flying for fun but also see a professional application. Drone techniques generally are very promising, but the adoption of drones is still very uncertain. To be able to define the opportunities it is mostly about the technical possibilities, but besides there are also entrepreneurs needed that want to work with it, a customer that sees value in the use of drones and a society that should accept the drones as part of a new environment. This involves ethical objectives and the need for new laws that make it possible to use drones in different application areas.

One of these promising application areas is Precision Agriculture (PA). The International Society of Precision Agriculture has defined this practice as follows: "Precision Agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production" (International Society of Precision Agriculture, 2019). A point about the agriculture industry is that it involves biological products that are extremely sensitive to environmental conditions and management practices. Consequently, precision agriculture provides an alternative and realistic means to reduce and optimize the use of potentially harmful compounds and thus can help to generate a healthier environment for the people (Zhang & Kovacs, 2012). That is why it is crucial for farmers to know everything about every inch of their fields, so they can adapt their practices accordingly.

The process cycle of Precision Agriculture follows three steps, namely: (1) data collection; (2) data interpretation; and (3) application (Raj R. , Kar, Nandan, & Jagarlapudi, Precision Agriculture, 2020). Since the spatial resolution from satellite images are coarse for small farms and the ground-based sensor are not able to cover a big area on the field, drone technologies are the promising solution to collect data at such temporal and spatial resolution (Raj R. , Kar, Nandan, & Jagarlapudi, UAV-based sensors in precision agriculture, 2020).

1.2 Research Objective

This research aims to examine the maturity of drone usage in precision agriculture while using different dimensions and what implications there are for its development. This will be done with a method that measures the readiness of drone usage in five different dimensions. This method is covered in a tool developed by Space 53, the Space 53 UAV Readiness Quick Scan. Besides, by using the tool, this tool will also be evaluated for the benefit of the client (Space 53). The evaluation of this tool is considered the sub-objective of this study.

Next to this research on drone usage in precision agriculture, other researchers will research drone usage in different fields. The aim of the researches is the same, however, researched in a different application area.

1.2.1 Research Question

"*How mature is the application of drones in the precision agriculture field and what is needed to develop this further?*"

By answering the research question, the objective of this research should be achieved.

1.3 Theoretical Framework

As mentioned before, drones are not unseen in today's precision agriculture. There is even a precision agriculture cycle defined which is UAV-based (Appendix A). In research conducted before, it was mentioned that small unmanned aerial systems (UAS) are shown to be a potential alternative for satellite imaging, because of their low cost of operation in environmental monitoring, high spatial and temporal resolution, and their high flexibility in image acquisition programming (Zhang & Kovacs, 2012). This research also mentioned that to provide a reliable end product to farmers, advances in platform design, production, standardization of image georeferencing & mosaicking, and information extraction workflow are required. However, since this research is conducted a while ago, 8 years, it can be suggested that the drone application in PA is already further developed. Previous research has also already concluded that drones are faster, more efficient, and cheaper than traditional farming systems (Lawani, 2018), which implies that drones should be used at all farms nowadays. By conducting this study, it will be examined how far the application of drones in Precision Agriculture is and what still needs to be developed to achieve matureness.

For managers, it is sometimes challenging to make a clear and well-documented assessment of technology readiness and risks and do this in key points in the product life cycle. However, in the 1970s, the concept of technology readiness levels (TRLs) was introduced. This is a discipline independent, program figure of merit (FOM) to allow a more effective assessment of, and communication regarding, the maturity of new technologies (Mankins, 2009).

There are nine different technology readiness levels (Appendix B). For the evaluation of technology readiness, these nine levels will be used as a measurement scale. The usage of technology and precision agriculture also raised some significant legal and socio-ethical questions inside Europe (Kritikos, 2017). A major legal challenge that is associated with Precision Agriculture concerns the processing of large amounts of information through technology. Almost all the data that is collected by the drones are subject to legal restrictions. Which makes the data collection and protection a challenge as well. Moreover, the amount of various agricultural stakeholders involved may also be considered a challenge. On the ethical side, the images collected by a drone could also involve imaging of a specific individual's behavior and actions. The question here is if this is ethically acceptable (Kritikos, 2017).

Due to the fact that not only the technology readiness is a concern when assessing the readiness of drone usage in precision agriculture, the scan tool from Space 53 will be used for the execution of this research. The Space 53 tool makes use of five different dimensions to assess the matureness of drone usage in a particular field. These five dimensions are technology, business, ethical, legal, and social.

The usage of the Space 53 tool will help to answer the research question mentioned above.

1.4 Academic Relevance

The academic relevance of this research can be identified as high. Up to now, the systematic evaluation of the matureness of a drone application field is rather one-sided. By the usage of the tool from Space 53, the evaluation will be done based on five dimensions, namely: technical, business, ethical, legal, and social.This makes the tool unique and a good improvement in the systematic evaluation of the readiness of the application of drones in any application field. Besides, by the usage of this tool, the tool will be evaluated as well. By evaluating the method that is used in the tool, improvement points might be found, so that future users of the tool can use it more easily.

1.5 Practical Relevance

The United Nations expects the world's population to rise to 9.7 billion by the year 2050. This causes agricultural production to rise by 69% between 2010 and 2050 (Meola, 2020). Which of course asks a lot from the farmers and makes them more important than ever. To meet this demand, farmers and agricultural businesses are heading more and more towards the usage of the Internet of Things for analytics and greater production capacity. The subject of technology and Precision Agriculture is more important than ever before. Because of this, practical relevance for this research is on the high side. Not only the drone companies need to know if they are on the right track, but also other stakeholders involved would like to know how ready the application area is for techniques like drones.

1.6 Research Design

The research will make use of some different steps, in order to answer the research question and to fulfill the objective of the research. To be able to answer the first part of the research question, namely how mature the application of drones in precision agriculture is, the tool from Space 53 will be used. This will be done by making use of people from the industry that have knowledge about the usage of drones for precision agriculture. It might be businesses that are already working with drones for precision agriculture or people with a lot of knowledge about the application of drones in this field. For the simplicity of the research, it will only be focused on businesses and people working in Europe. Next to that, Precision Agriculture is rather broad and can involve a lot of aspects. That is why for this research, the focus will only be on the first half of the Precision Agriculture cycle from Appendix A. This could be called the sensing and the moving part. The drones that are part of the second half of the cycle, where the drones would make decisions and act upon gathered data, will be left out.
After multiple people have filled in all the necessary information into the tool, an analysis will follow. With the analysis of the results, the readiness of the application of drones in the precision agriculture field will be defined by the usage of the five different dimensions. For the sake of the research, experts in this application area will be contacted to ask for their expert opinion about the tool results. This will be done by the usage of a semi-structured interview, where the expert and the researcher together will evaluate the results. In this way, it can be defined how the application area of precision agriculture needs to develop itself. After using the tool and evaluating the results, for the sake of the client, the tool will be evaluated, and improvement points will be identified.

2. LITERATURE REVIEW

A significant amount of studies has been dedicated to precision agriculture and drone-based sensors. However, more than 50% (around 3000) of the papers are published after 2016, with almost 90% of all the papers published after 2013 (Raj R. , Kar, Nandan, & Jagarlapudi, UAV-based sensors in precision agriculture, 2020). The trend of research on drone-based sensing and PA is due to improved efficiency of UAVs and the scanning of imaging over the last five years. A sensor can be defined as a device that records that something is present or that there are changes in something (Cambridge Dictionary, 2020). With the rising trend of PA drones and sensing, the dissatisfaction of satellite imaging for making decisions on the farm in real-time is growing. The advantages of drone-based sensing vs satellite sensing can be found in Appendix C (Raj R. , Kar, Nandan, & Jagarlapudi, 2020). The collection of the needed data can be collected via UAVs, satellite images, and manned aircrafts (Smith, 2017). Since the aircrafts are flying fast and cannot get as low as a drone, the quality of the images is lower than by using a drone. However, more information will be received, and better resolution images compared to satellite images. When comparing the costs of the three systems, UAVs have the lowest cost per acre. Drones do need a big investment in the beginning since these systems have the highest acquisition costs of the three systems. But in the end, drones are considered the best system to use for Precision Agriculture (Smith, 2017).
The growing interest in drone usage in Precision Agriculture implies that the drones are already in use. To get a better overview of the current state of the PA drones, literature will be reviewed about the present use of drones in Precision Agriculture. This involves the challenges currently present, the sensors on the drones, and some examples of use cases.

2.1 Current State

The Association for Unmanned Vehicle Systems International states that 80% of UAVs will be used for agricultural purposes soon (Association for Unmanned Vehicle Systems International (AUVSI), 2013). Therefore, drones will play an important role in the further development of the agricultural sector (Radoglou-Grammatikis, Sarigiannidis, Lagkas, & Moscholios, 2020). In the same paper, the primary objectives of PA are outlined, which are: to increase the yield of crops; to improve the quality of the products; to make more efficient use of agrochemical products; to save energy; and, to protect the physical environment against pollution.
Most of today's drone applications in agriculture have been on grain crops, i.e. wheat, corn, and soy. However, drones are also possible to use for orchards, and tree nurseries. The drones could be used here for:

- Taking inventory of tree height and canopy volume;
- Monitoring tree health and quality;
- Managing water, nutrients, pests and disease in-season;
- Estimating fruit/nut production and yield; and,
- Creating marketing tools (video for promotion or sales of trees and fruit)
  (American Society of Agronomy, 2020).

Next to the application in grain crops, orchards, and tree nurseries, there is also already a possibility for drones to be used in greenhouses. There are different applications where UAVs could be used inside greenhouses:

- Safe inspection of structural components
- Sales and marketing
- Applying shading compound
- Crop scouting/monitoring

- Crop inventory (Robbins & Mari Maja, 2018)

Out of these enumerations can be concluded that drones have a very broad spectrum of application possibilities in the agricultural field.

2.1.1 Challenges

Some challenges have also been identified by previous research, for the implementation of drones in precision agriculture. The current PA technologies are not used to their full potential, mainly due to the trade-offs and high complexity characterizing farmers' decisions. This has been called the "problem of implementation" (Nkao Ondoua & Walsh, 2017). Various causes have been identified for the low adoption rate of PA technology, which are: high costs of investments and learning, extra work, cost/benefit ratio, doubts in the credibility of the technologies, farmer's perception of usefulness, ease of use, farmer's age and education level, and resource credibility (Nkao Ondoua & Walsh, 2017).

First, the financial situations of many farmers are considered a challenge in adopting drone technology. Drones require a substantial capital investment and technical expertise, making them difficult to acquire for small-to-medium farmers since they cannot benefit from economies of scale (European Commission, 2018). There are different ownership models possible here. The drones could be bought and used by the farmer himself, a cooperation, or operated by a drone/technology company. Next to that, the drones could be offered as a service, where the farmer would book and pay per flight. However, regardless of the ownership model, investment is needed, and the drone companies still need to prove that drones are better than existing processes.

To find out the quality of data collected by the drones, a test has been conducted by Chateau Lagrange, a vineyard in the Bordeaux region of France. Drones and sensors were trialed and tested and compared to reference figures they had compiled. The study showed that the technology was commercially premature and not yet reliable as a standalone solution. The problem of the too low quality of data can be considered a matter of time. So, even though the quality of drone images is not yet always perfect, there is progress since companies are already working on higher quality drones and sensors.

As stated above, the ability of farmers to modernize is also a challenge involved. Over 56% of the farmers in Europe are aged above 55 (European Commission, 2018). And according to a survey conducted by the United States Department of Agriculture in 2017, 73% of farms have computer access, but only 47% of farms are using computers for business purposes. Next to that, 39% of farms use a smartphone or a tablet for farm business (United States Department of Agriculture, 2017). This data raises the question that not only the technology is not mature and developed enough. But also, the farmers themselves might not be ready for the introduction of drone technology on their farms.

2.1.2 Drone-based sensing

Even though it is not widely integrated yet, the PA drones' possibilities are already quite advanced. It is possible to install different kinds of optical sensors on drones, i.e. infrared cameras, RGD cameras, multispectral cameras, hyperspectral cameras, thermal cameras, etc. The aforementioned seonsors make drones applicable to study different crop-related parameters. The possibility of detecting, by using a drone and an infrared camera, where large irrigation is needed, or where leafage disease is spreading can help agriculturist to save time, water and reduce the usage of pesticides. Meanwhile, advanced farming will increase crop productivity and quality (Daponte, et al., 2019). The three most important sensors here are thermal, multispectral, and hyperspectral. Today's drone-based sensors are stated to be smaller, lighter, more powerful, and often more specialized than the previous aircraft-based sensors (Precision Hawk, 2020). Thermal sensors measure the relative surface temperature of objects (Hatcher, Thermal sensors, 2020). The thermal cameras form an image by using infrared radiation. In agriculture, this could be used to gain insight into heat stress, water use, and plant metabolism. Multispectral sensors, on the other hand, collect red, green, and blue wavelengths of light (visible wavelength), as well as wavelengths that fall outside the visible spectrum (Hatcher, Multispectral sensors, 2020). In agriculture, these sensors can be used to perform more effective crop management with plot-level statistics on plant count, height, vigor, leaf area, and canopy cover. Lastly, there are the hyperspectral sensors. These sensors collect data as a series of narrow and contiguous wavelength bands providing a high level of performance in spectral and radiometric accuracy (San Souci, 2020). The hyperspectral sensors are used in agriculture to protect against yield loss, which will be done through early detection and identification of diseases.

2.1.3 Use Cases

Currently, drones are already used in agriculture for different purposes. By pointing out some different cases of drone usage, an overview will be created of what is already possible and used at the moment. (Pix4D, 2019)

Nitrogen is the most used fertilizer worldwide. Without this, plants simply cannot thrive. Nevertheless, farmers are striving to reduce their use of fertilizer to align with the environmental goals. To still give the plants the nutrients they need while reducing fertilizer use, farmers are moving towards Precision Agriculture. Drone mapping and prescription maps are used for variable-rate fertilizer applications. The variable rate fertilizer application will meet the needs of each plant. By doing this, over-fertilization is prevented.

Another case of drone usage is for mapping the optimal harvest time. It's an issue that is already present for decades: when is the right time to harvest? Harvesting too soon or too late will result in less taste and nutrients, which will also mean lost profits. A custom index has been created by Agrarpohl to measure the ripening of plants in a cornfield. Here, the optimal moisture level is between 60-70% (30-40% dry matter). When the corn would be harvested below 30%, too little starch will be in the corn. On the other hand, above 35%, higher losses can occur during the storage of the corn. By using mapping, the optimal harvest time can be determined. By using these drones and the index, an extremely high spatial resolution will make it possible to precisely evaluate individual fields or parts of the field (Pix4D, 2019).

Something very different where drones in PA could be used for is the insurance of crops. When damage occurs to the fields, farmers need to file a written notice of damage to be able to receive coverage. This can be the case when there is for example a flood, infestation, or a storm. A drone could fly over the field to collect data and create different maps. With this data, farmers get verifiable proof that can be used for their compensation.

To summarize, it can be stated that drones are already fully in use in Precision Agriculture with a growing interest by researchers, which can be seen in previous research conducted.

However, there are still some challenges involved with the current state of drones. To be able to measure how far developed drone usage is at the moment, the matureness has to be measured. Below some different methods will be explained.

2.2 Theoretical Framework

Currently, the readiness of drones is mostly measured on the technological level. This is done by the usage of Technology Readiness Levels (TRLs) (Mankins, 2009). The TRLs are used on specific points in the development process, when an organization attempts to determine the maturity of new technology. These points are called technology readiness assessments (TRAs). There are nine different technology readiness levels. Since these nine levels will be used to measure the technology readiness inside the Space 53 tool, the nine levels will be explained below (see also Appendix B).

1. ***TRL1: Basic principles observed and reported***

This is the lowest level of technology maturation. In this level, basic scientific research has resulted in the observation and reporting of basic principles, which begin to be translated into more applied research and development.

2. ***TRL2: Technology concept and/or application formulated***

After these basic physical principles are observed, practical applications of those characteristics can be identified or "invented". At this level, the applications are still rather speculative, there is no specific experimental proof or detailed analysis to support the conjecture.

3. ***TRL3: Analytical and experimental critical function and/or characteristic proof-of-concept***

In this step, the active research and development are initiated. This has to include analytical and laboratory-based studies. Which should constitute "proof-of-concept" validation. Demonstration of technical feasibility using breadboard or brass board implementations that are exercised with representative data.

4. ***TRL4: component and/or breadboard validation in a laboratory environment***

Following a successful "proof-of-concept", the basic technological elements involved must be integrated to establish that the "pieces" will work together to achieve concept-enabling levels of performance at the levels of a component and/or breadboard.

5. ***TRL5: component and/or breadboard validation in relevant environment***

At TRL5, thorough testing of prototyping in a representative environment takes place. The basic technology elements get integrated with reasonably realistic support elements. In this level, the prototyping implementations conform to the target environment and interfaces.

6. ***TRL6: System/subsystem model or prototype demonstration in a relevant environment***

At TRL6, a representative model or prototype system would be tested in a relevant environment (ground or space). At this level, several-to-many new technologies might be integrated into the demonstration.

7. ***TRL7: System prototype demonstration in the expected operational environment***

Requires an actual system prototype demonstration in the expected operational environment. The driving purpose for achieving this level of maturity must be tied to assuring system engineering and development management confidence. But limited documentation is available.

8. ***TRL8: Actual system completed and "qualified" through test and demonstration***

All technologies go through TRL8. This can be considered the end of true "system development" for most technology elements. The technology is fully integrated with operational hardware and software systems. Most of the user documentation, training documentation, and maintenance documentation is completed. Verification and validation (V&V) are completed.

9. ***TRL9: Actual system "flight-proven" through successful mission operations***

All technologies that succeed in being applied in actual systems go eventually to TRL9. The technology is fully integrated with operational hardware/software systems and has been thoroughly demonstrated and tested in its operational environment. All the documentation is completed and there is a successful operational experience.

The nine different technology readiness levels will also be used to measure technological readiness in the tool from Space 53. However, not like other matureness tools, the Space 53 tool will not only measure the readiness on the technical level but also on four other dimensions to be able to give a complete overview of the drone readiness levels in precision agriculture.

2.2.1 A Multidimensional Framework

The European Parliament is not sure how ready the EU law is for the legal and ethical questions that arise by the usage of drones for precision agriculture (Kritikos, 2017). The collection of large amounts of data can be an example of a legal question, since these are subject to legal restrictions based on the GDPR law. Besides, filming people without their consent is not allowed due to their privacy. But people may be caught on camera when they walk by a field during filming. It can be stated that it is not sure yet how far developed the drone technologies are when it comes to legal and ethical issues. Next to that, the research from the European parliament addresses that there is a lack of a so-called critical mass of independent advisors. Farms are mostly privately owned by sole owners. Which raises the technical accessibility and affordability challenge. These challenges can be associated with the business domain. But it could also be linked to the social domain. Since it involves stakeholders.
Out of this, it can be concluded that it is important to measure the readiness on business, ethical, legal, and social levels, besides technology readiness. That is why Space 53 has developed a tool that will examine all these five dimensions. First, the drone readiness will be examined on the technical level. The technical readiness will be examined in six different categories. Which are: total system configuration; drone management components; flight components; application components; back end; and system integration. For measurement, the nine technology readiness levels (TRLs) will be used, as explained before. The second dimension of Space 53's tool is business readiness. With business readiness, we measure the current state of the business and stakeholders. Again, this will be done by the usage of six different categories. Which are: The customer; the value proposition; the market forces; the alliance partners; the value delivery process; and financials. The statements in this section will be measured using a Likert scale. Next is the ethical readiness tool. The five categories in this section are purpose; safety; automation;

distance; and value shifting. Fourthly, legal readiness will be examined. Here, the five categories are public safety; environmental burden; privacy; data protection; and liability. Lastly, there is the social readiness, which will be measured differently. The user of the tool has to answer questions on the categories: stakeholders; design; and acceptance. It is asked to choose between four different scenarios.
By filling in all the information needed in the five different dimensions, the tool will calculate the overall readiness. Out of this, it can be concluded how mature drone usage is. And for this research, that would mean how mature the drone usage is in the Precision Agriculture field.

The implementation of drones on the farms is a new radical innovation that takes time to fully implement. Currently, drone technology can be placed in the niche technology from the multi-level perspective model (Geels, 2002). This model consists of three levels: socio-technical (ST) landscape; socio-technical (ST) regime and niche. The ST regime refers to the rules that constrain and enable activities within communities. Technical trajectories are located in the ST landscape, which refers to wider technology-external factors. The concept of the landscape is harder to change than the regimes. Landscapes however do change, but slower than regimes. The regimes generate incremental innovations; however, radical innovations are created in the niches. The niches function as so-called incubator rooms.
By defining the matureness level of drones in precision agriculture, it can be stated how far developed the niche technology is. The further developed and implemented in the precision agriculture field, the more implemented in and part of the regime the technology is.

3. METHODOLOGY

As mentioned above, the PA drone's readiness will be measured by using the tool from Space 53. By doing this, the research question will be answered. As a result, it will be possible to conclude how mature the application of drones in the precision agriculture field is, and what is still needed to develop this further.
In this research, the data will be gathered by the usage of qualitative research. Qualitative research is a scientific method of observation to gather non-numerical data (Babbie, 2014). For this research, the data that will be collected to answer the research question can be considered non-numerical. The research will make use of some different steps, in order to answer the research question and to fulfill the objective of the research. Here, 3 sub-questions could be defined:

1. How mature is the application of drones in the precision agriculture field?
2. What is still needed to develop this further?
3. What are the improvement points of the UAV Readiness Quick Scan Tool developed by EFRO/Space 53?

To be able to answer the first sub-question, the tool from Space 53 will be used. To get the right results out of this tool, various people need to fill in the tool. For the simplicity of the research, it will only be focused on businesses and people working in Europe. Next to that, precision agriculture is rather broad and can involve a lot of aspects. That is why for this research, the focus will only be on the first half of the precision agriculture cycle from Appendix A. This could be called the sensing and the moving part. The drones that are part of the second half of the cycle, where the drones would make decisions and act upon gathered data, will be left out. Another reason for not studying the whole cycle is that different drones are used in different parts of the precision agriculture cycle. Those different drones conduct different tasks and these different functions involve other ethical issues, resulting in a different ethical assessment needed (Brey, 2012).

To start, people need to be contacted to ask if they want to participate in the research. First, it is needed to know which people are needed. Here, three categories are defined: experts, farmers, and drone companies. The experts are researchers, professors, consultants, and other people working in the sector that have a lot of knowledge about the intersection of technology and agriculture. These experts do not have to be European, as long as they know the use of drones in European crops. The farmers are farmers that are already using drones in their businesses. Their farm has to be located in Europe. Lastly, there are drone companies. The drone companies have to make or operate drones that are applicable in Precision Agriculture. Just as before, the drones have to be in use in the European market. People from all three categories will be contacted to be able to draw a conclusion that involves all parties involved. After defining the three categories, the search can start. For this, a post on LinkedIn will be made to try to reach the right audience. In the post, a call will be made to ask for the experts, farmers, and drone companies that are willing to participate in the research. Next to that, an existing network will be contacted to ask for their collaboration. Lastly, an internet search will be conducted to search for other people that are still needed. The goal for the number of people would be as much as possible. However, the gathered data still needs to be processed in the time frame of this research. That is why 15 participants would be the maximum.
After gathering the participants for the research, the actual usage of the tool can start. First, the participants need to receive the tool to be able to fill it in. For all participants to start with the same information and to have some background information, an extra explanation will be given at the beginning of the survey (Appendix D). This to make it easier and more efficient to fill in the tool. The researcher will not help the participants with filling in the tool, since it is also necessary for the research to find out what the weak points of the tool are. Once all participants filled in the tool, the data will be gathered, and an overview will be made of the collected data.
Thereafter, the collected data needs to be analyzed to be able to answer the second sub-question, to find out where there is still development needed. To reach this result, an expert's view is needed. That is why the scores generated by Space 53's quick scan tool will be analyzed through an expert interview. For the interview, an expert needs to be found that has enough knowledge about drones and precision agriculture. The expert interview will take place as a semi-structured interview. An interview guide will be prepared for the interview (Appendix E). By using the interview guide, it is sure that all important topics are covered (Robert Wood Johnson Foundation, 2008). Choosing for a semi-structured interview still gives the option to ask other and extra questions besides the interview guide. The questions will be divided into five different categories, linking to the five different dimensions. Asking these questions should result in some implications that can help improve the readiness level of drone usage in precision agriculture.

Finally, the collected information from the interview will be used to draw a conclusion about the matureness of drone application in precision agriculture and to come up with development points of this application.

While doing the research and using the tool from Space 53, extra attention will be paid to the user-friendliness of the tool. By gathering the improvement points for the usage of the tool, a recommendation will be made to Space 53. This makes it possible to answer sub-question 3 and to reach the sub-objective of the research.

To sum up, participants will be looked for and divided into three categories: experts, farmers, and drone companies. The participants have to fill in the survey that will be sent to them. The results from these surveys will be assessed and analyzed by the usage of a semi-structured expert interview. Out of the results, the state of maturity from PA drones can be concluded. The participants will be asked to assess the usefulness of the tool and a recommendation will be given to Space 53 about the improvement points for their scan tool.

4. RESULTS

Within the results section of this paper, the results acquired from the Space 53 tool and the expert interview will be discussed and elaborated upon. At the end of the results section, the evaluation of the Space 53 tool will be discussed.

4.1 Quick Scan Tool

To start collecting the needed data, participants were needed. Participants were looked for on different channels. For example, posts were placed on LinkedIn, special groups for drone users in agriculture, and an existing network was contacted. As mentioned before, all the people reached out to were part of one of the three categories, namely; experts on agriculture and technology, farmers using drones, or drone companies with drones operating in precision agriculture. All participants were asked to fill in the survey from the sector's perspective. At the beginning of the survey, some background information about drones in precision agriculture and the research was given (Appendix D).
The respondents had a two-week timeframe to fill in the survey. In the end, 20 people started filling in the survey. However, not all responses were completed enough to take into account for the results. That is why only 12 respondents were taken into account for calculating the readiness levels of the five dimensions. From the 12 respondents, 1 was a farmer, 1 was a drone company and the other 10 were experts on agriculture & technology. By generating an average with the results from the respondents, Figure 1 was created.

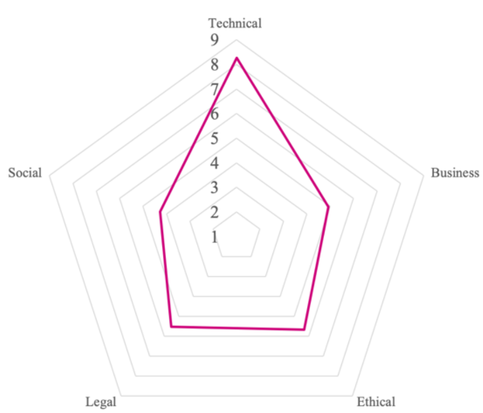

Figure 1. Readiness levels in 5 different dimensions

Based on Figure 1 it can be stated that out of the five different dimensions, technology is by far the most mature/developed one. The social dimension, however, is the least mature/developed. Out of all the subsections from the different dimensions, the financials had the lowest score of 3.38, see table 2.

4.2 Expert Interview

After collecting and processing the data. An expert interview was held to be able to evaluate the results through the eyes of a professional on this particular topic. The expert can also give insight into what the implications are for developing drone readiness in precision agriculture. The interview was semi-structured by following the interview guide from Appendix E. The goal of the interview was to analyze the data collected and acquire insights in what still needs to be developed further for a higher matureness level. The expert who was interviewed is CEO and co-founder of an international company that focusses on offering drone services and data analysis for the agricultural sector. By offering this service, the expert wants to create a match between the agricultural demand and the innovations that can satisfy this demand. During the interview, all five dimensions were discussed. Afterward, the connection between the different dimensions was evaluated.

4.2.1 Technology readiness level

The technology readiness results showed a high matureness level of 8.25 (see Table 1), the highest result of the five different dimensions. With these results, it could be implied that drones are ready for usage in the agricultural sector. The expert partially agreed with this result. However, he did still see some improvements that could be made. The drones themselves are indeed well developed over the last years. Nevertheless, he mentioned: "*The technology readiness of the drone application in the agricultural sector disappoints us mostly. That mainly has to do with the drone data being processed in one system, saved in another system, and applied in a tractor. The different components are working fine, however, the integration of the full system still needs improvement and I would score it lower than an 8.25*." So, even if all the systems themselves are working fine, it is the integration between the systems that needs improvement. Especially if one of the systems is older than the other. If everything was purchased new, it would already be easier to implement. The integration between older devices (i.e. tractors, GPS systems, task cards, etc.) and new technology (drones) is still not *Plug & Play* and could use some improvement before really being mature and "*ready to purchase*".

Table 1. Technology readiness level

Technical readiness level	**8.25**
Drone management components / functions	7.75
Flight components / functions	8.25
Application components / functions	8.25
System integration	8.19
Back end	7.90

4.2.2 Business readiness level

Even though the technology results were pretty high, the business readiness level on the other hand scored pretty low with a 4.93 (see Table 2). As one reason for the business readiness level being so low, the expert talked about the agricultural sector being so fragmented. This means that the sector is broken into small parts, for example independent small farms. The sector being fragmented makes it hard to build a broad substantiation of the business case and financial results. The expert also mentions the sector dealing with a *technology push*, where there are a lot of companies offering technological solutions that are not needed. This creates a mismatch between supply and demand.
The limited financial substantiation of drone technology in the precision agriculture section can also explain the financial readiness level of 3.38 being so low. Not only the sector being

fragmented makes it hard for the creation of a good business case, but also the drones being weather dependent is important here. The drones are not always deployable, they depend on seasonal influences.
As the main reason for the business readiness being so low the expert mentioned: "*If I could sell you something for €10 and it would give you €50, then it is not that hard to think about buying it. So, at the moment it is partly the financial substantiation not being there and focusing on the wrong applications of technology. The money would not be the problem once it is proven*.". So, once there is a financial substantiation, money will no longer be a problem for implementing the technology on the farm.

Table 2. Business readiness level

Business readiness level	**4.93**
The customer	7.06
The value proposition	5.00
Market forces	4.84
Alliance partners/network	4.13
The value delivery process	4.80
Financials	3.38

4.2.3 Ethical readiness level
For the ethical readiness level measurement in the Space 53 tool, the respondents had to answer a set of questions and at the end indicate how ethically ready they would indicate the sector. The participants scored the ethical readiness level on average with a 5,67 (see Table 3), indicating ethical readiness to be the second-highest of the different dimensions. The expert mentioned that privacy is probably not a very big issue in the agricultural sector since it does not involve filming human beings. He, however, sees a bigger ethical challenge with the collection and ownership of data, since drones can be used to make the farmers live easier or help their company generate a higher profit. On the other hand, drones could be used to pressurize or watch farmers.
There are also a lot of positive ethical benefits for the agricultural sector. First, the environmental benefit. The usage of drones makes it possible to work in a more environmentally friendly way, for example by using fewer pesticides on the field. The other benefit is drone usage giving a boost to the image of the agricultural sector. This could not only be linked to ethical, but also the social dimension.

Table 3. Ethical readiness level

Ethical readiness level	**5.67**
Participants own estimation	5.67

4.2.4 Legal readiness level
The average score of the legal readiness level was 5.54 (see Table 4). However, there was a big difference between the different categories within this dimension. Data protection had a very high score of 8.67 and the other categories were all around 5.00.
As a professional drone user, it is only allowed to fly over someone's land if the owner approves it. However, in the case of agricultural drones, this is not a problem since the owner of the land is the one that will use the drone or will pay for the drone service. Also, since being able to see everything on Google Maps, it is made easier to make aerial pictures. Since the drones are only flying over land and will not film human beings, it means there are fewer laws and regulations involved. Currently, for data protection the only regulation there is, is a code of conduct formed by the branch organization. Out of the results from the Space 53 tool, it can be stated that the participants see this as enough regulations for good data protection.
Liability however still has some improvement points. Of course, companies have liability insurances for the company themselves and their drones. However, the service of drones offered to farmers comes with a 0% warranty. The supplier does not guarantee the accuracy of the offered product or data captured by the drones. The reason for this is that drone technology is relatively new, and a lot of aspects are not proven. As mentioned in the business readiness level, it is also still hard to prove the financial benefits of drone usage. With the presence of all these uncertainties, it is impossible to guarantee the customers the accuracy of the technology. By researching more the accuracy and effectiveness of the drone technology, the liability readiness level could be raised to a more mature level, which will also result in getting a higher legal readiness level.

Table 4. Legal readiness level

Legal readiness level	**5.54**
Public safety	4.67
Environmental burden	5.26
Privacy	4.47
Data protection	8.67
Liability	4.60

4.2.5 Social readiness level
Lastly, we come to the social readiness level. The social readiness level was scored the lowest of the five different dimensions with a 4.27 (see Table 5). Part of the social readiness level is the stakeholders, the design, and acceptance.
Within the agricultural sector, there are a lot of stakeholders involved. One of the most important ones is the suppliers, and among them, are the chemical suppliers. For these stakeholders, the expert mentioned: "*Normally you would spray 100% of the field with herbicide, weed control. You could imagine that if we create a task card that states that now you only have to spray 5% of the field and could save 95% on herbicide, the chemical supplier will not be thrilled with happiness about this*." It could be stated that for the readiness level of stakeholders, there is still improvement needed. However, there is a rising trend in their acceptance. This is also due to the fact that positive effects on the environment are becoming more important, also in politics and for public opinion.
The technological innovation could also result in different stakeholders. The agricultural sector still has a quite dusty image. By using high-tech and Precision Agriculture, young people will get enthusiastic about working in the agricultural sector. This will result in new knowledge, people, and skills entering the sector.
When a new technology arrives on the market, the acceptance of the farmer is needed to make the new technology into a success. It is hard to gain their acceptation, especially when it is not proven yet that the technology works well or will be profitable. Nonetheless, it is easy to lose their acceptance. When a scandal with data usage and abuse will arise, the acceptance of drone technology will drop again.

Table 5. Social readiness level

Social readiness level	**4.27**
Stakeholders	4.30
Design	4.23
Acceptance	4.28

4.2.6 Connecting the different dimensions

Between the five different dimensions' readiness levels, a relation can be identified. Technology is stated as very mature, and the other four dimensions are all halfway the scale. The reason for this is, to quote the expert: "*Technology is pretty high, this is because the sector is driven by technology ... This results in technological innovation being relatively easy and fast. Laws and ethical aspects will be taken into account later on*."

Another reason here is, again, the *technology push* being present in the agricultural sector. Wanting to use technology just because they want to have the technology, not for the added value of the technology. By focusing only on technology, the social aspects of the innovation will be left out and will become underdeveloped.

To summarize the results gained from the expert interview, technology can be defined as the most developed dimension. The drones themselves are "ready to go". However, the implementation with the other machines and devices present in Precision Agriculture still needs improvement. For the development of the business readiness level, improvement in the financial business case is needed. Nowadays, it is not possible to substantiate the advantages with proven facts and figures. For ethical readiness, the biggest problem is still the handling and collection of data. However, privacy is not the biggest issue since there is no filming of people involved. This also applies to legal readiness, where mostly the liability needs improvement. This could be done by, again, proving that the technology is good and efficient. Lastly, social is the least ready of all the dimensions. This is mostly because the stakeholders have to get on board and the farmers still have to gain trust in the technology to be able to accept the drones on their field.

4.3 Space 53 Tool Review

In addition to testing the readiness level of drone technology in precision agriculture, the sub-goal of this research was to examine the UAV Readiness Quick Scan Tool developed by Space 53. At the end of filling in the Space 53 tool, the participants were asked to give their opinion about the tool. The answers of the participants were predominantly negative since they still saw some improvement points needed for the Space 53 tool going live for organizations to fill in. Some of the quotes are:

> "*You should divide the questions into drone-users, drone-developers, and experts. Combining different questions for the different stakeholders can give more insights.*"

> "*Long and difficult to follow*"

> "*Comprehensive approach, challenging the person surveyed to consider drone use from a holistic perspective*"

> "*… It's good to combine technological innovation with social innovation aspects. I miss system innovation aspects*."

From the quotes above, it can be stated that the Space 53 tool still needs to be developed further. Among the answers, the ethical tool was stated to be "*completely unclear*", there was too much text written out in the tool and the questions were "*quite complicated*". The respondents also mentioned that the PDF overview generated in the end was unclear and did not provide a good overview. The respondents would have liked a graph or graphic to be able to see the results at a glance.

Next to their opinion and improvement points, the participants were also asked to score all five readiness level tools on how easy the tool was to fill in; if the tool provides inside in their drone; if the tool provides insight in what to do next; if the was helpful; and if the tool can guide drone development. The participants were asked to score the above on a scale from 1-5. With 1 being not applicable at all and 5 being totally applicable. For almost all the questions and all the tools, the questions were scored between a 1 and a 3. For the question, if the tool was easy to fill in, all tools never scored higher than a 2, indicating that no one found the tools easy to fill in.

Out of the given comments, a recommendation for Space 53 to develop and elaborate further on their UAV Readiness Quick Scan can be concluded. First. the tool should be easier to fill in for non-academic people. This can be done by using easier to follow language and reducing the text length in the survey to create a more clear and better overview. It might also help to not let the participants choose their order of tools. By using a set order, the overview is clearer and there is a more logical order between the different tools.

Next to that, it could also help to make the different scans available for different stakeholders being part of drone development. By letting different people fill in the five readiness tools, the best result could be achieved. Because in this way, the person with the most knowledge about that particular dimension will be able to fill in only that dimensions' tool.

5. DISCUSSION/CONCLUSION

The final chapter of this paper will give a conclusion for the results and data conducted during the study. Besides, the managerial implications, the limitations of the research, and the recommendations for future research will be discussed.

5.1 Conclusion

In this research, a new approach to examining the matureness and readiness of drone technologies was presented. The research did not only measure the technological readiness, but also the readiness levels of the business, ethical, legal, and social dimensions. The study aimed to find out how mature the application of drones in the precision agriculture field is and what is still needed to develop this further. Out of the gained results from the study, it can be concluded that the technology readiness of drones in precision agriculture is predominantly high. However, the other four dimensions are left behind when it comes to their matureness level. The drones could be seen as 'ready to go', but implementation with existing machines and technology still needs more research and development. For the business dimension, a business case with financial substantiation needs to be developed to be able to proof the effectiveness and efficiency of drone usage in the agricultural sector. By proving this, the liability would also get higher, since the data generated by drones can then be guaranteed to be correct. This would result in a higher readiness level on the legal dimension. On the ethical side, the processing and collecting of data need to be further protected for the farmers to get a higher trust in the drones' technology. The social dimension currently has the lowest readiness level. Here trust is also important. The farmers need to gain trust in the technology to accept, and eventually use, the drones on their field. Again, the financial substantiation of the drones is important here. The farmers need the security of knowing that drones will add value to their farm and will be profitable.

Besides, time is important. Once drones are on the market for a longer time and more common to use, farmers will get used to and more familiar with drone technology.

For the sub-goal of this research, to examine the Space 53 UAV Readiness Quick Scan, it can be concluded that development is needed to make the questions clearer and easier to understand. Also, a better overview needs to be created for the results gained by the Space 53 tool.

It can be stated that the technology is the highest developed dimension, however, for the rest of the dimensions a lot of development is still needed to reach maturity.

5.2 Managerial Implications

The research has some different implications for future research, drone development, and the precision agriculture field.

There is more research needed to be able to give a good overview of how far developed drone technology in precision agriculture is at the moment. However, this research was one of the first that did not only measure technology readiness but focused on five different dimensions; technology, business, ethical, legal, and social readiness. The research made clear that researchers should not only focus on technology readiness, but also other aspects involved by the development of new technology. By reviewing previous research and literature, it was found that none of the studies involved measuring readiness on different dimensions at the same time. It was either technology readiness or looking at the ethical and social aspects. The results of this study show that even though the technology might be well developed, the business, ethical, legal, and social readiness stayed behind, which results in a low overall readiness level. The way of data collection in this research is unique for the assessment of emerging technologies and highlights the importance of involving different actors and knowledge from different fields to evaluate the matureness level of, in this case, drones. The study also shines a new light on the importance of incorporating business and social aspects in accessing new technology and radical innovations. Möller has also defined in his study the importance of sense-making and agenda construction during the process of radical innovation development (Möller, 2009). The core issue in developing this technology into a valuable business is to acknowledge the importance of involving all actors to create a good business model. Making use of agenda construction can help to reduce uncertainty and ambiguity inherent in radical emergence.
By making use of the technology adoption life cycle from Rogers, customers can be defined in 5 categories when it comes to their acceptance of new technologies (Rogers, 1995), namely: innovators; early adopters; early majority; late majority and laggards. The drone technology is currently only accepted by the innovators and early adopters. After further improvements and developing the business, ethical, legal and social dimensions, drone technology can be easier accepted by the early majority and the categories afterward.
The methods used in this study are new to the field of examining the matureness level of technical innovations. The Space 53 tool will, later on, be used by companies to review their drone readiness level. By giving recommendations to Space 53 on how to develop the UAV Readiness Quick Scan, the tool will become more developed and clearer for the users. The Space 53 tool will make it possible for the precision agriculture sector to review the drone development in their sector, besides the results per company.
The agricultural sector could use the results from this study to make it clearer that it is not only the technology that needs to be developed and implemented. But that it is very important to invest in creating a good substantiated business case where especially the financial benefits of drone usage are highlighted. Establishing this business case will also positively influence the maturity levels of ethical, legal, and social dimensions. Since the business case will prove the effectiveness and efficiency of drone usage in precision agriculture, customers will adopt to drones easier and faster.
During the expert interview, the technology push present in the agricultural sector came forward. The sector should look out for implementing drones on the field, just for wanting technology present in the sector. The drone technology should be implemented and used for their added value.

5.3 Limitations & Future Research

While researching for this paper, there were some limitations involved. The research took place between April 2020 and July 2020. This timeframe involved the COVID-19 pandemic that resulted in lockdowns all over the world. The pandemic made companies focus on surviving the economic loss and struggles they were facing, which resulted in less attention and time for academic research. This also affected this research. Due to the pandemic, it was not possible to meet with other people and it was harder to find respondents that were willing to take the time to fill in the Space 53 tool. Due to the social distancing restrictions going on in The Netherlands, the expert interview took place online.
The lower number of respondents than wanted resulted in less accurate results for the readiness levels of the five different dimensions. The respondents had a two-week timeframe to fill in the survey since the full research had an 11-week timeframe. This can also be defined as a reason for not enough respondents. When research would be conducted by using a higher number of respondents, the readiness level of drone technology could be calculated more precisely. That is why more research is needed in measuring the readiness level of drone technology in precision agriculture.
The respondents that filled in the Space 53 tool defined the tool as being unclear and the questions were hard to follow. The tool being unclear is also a factor that influenced the results of the study. This also resulted in some of the respondents only filling in the Space 53 tool partly; for example, not filling in the legal dimensions tool. 6 out of the 12 participants did not fill in the readiness tools of all five dimensions. This meant that some participants were not able to give a complete insight into how mature and developed they would score the drone technology in precision agriculture over the five different dimensions.
Overall, it could be stated that the number of participants in the research was the biggest limitation, resulting in more research needed.

For further research on this subject, it would be recommended to make use of a bigger group of respondents to fill in the survey. By using a higher number of respondents, the results would be more reliable. The current research was focused on the whole of Europe. For future research, it would be easier to focus on one country at a time. This due to different rules and regulations currently present in the agriculture sector. To measure the drone readiness level in precision agriculture more accurately, a better-developed tool would be needed. This could be achieved by implementing the comments given by the respondents of their experience with the Space 53 tool. The tool should be easier to fill in and the questions should be clearer. Besides, the tool should generate a clearer overview for the respondents to view their drone readiness level. This could be

achieved by using graphs and graphics. The generated results are not only useful for the companies themselves but also for the whole precision agriculture sector.
It is recommended to conduct further research on the topic of drone readiness in the precision agriculture field.

To conclude, the *technology push* present in the sector makes the technology dimension precursor. This study shows the importance of also taking business, legal, ethical and social dimensions into account to make drones valuable assets on the farm.

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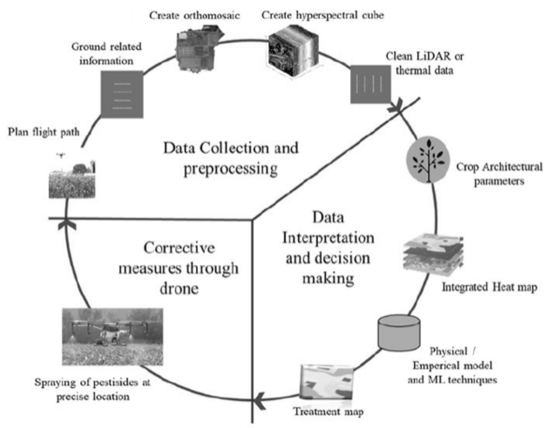
8. APPENDICES

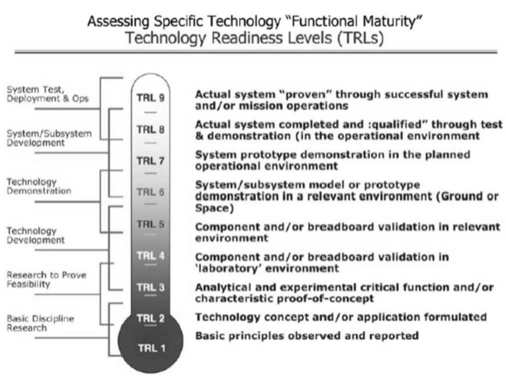
Appendix A: UAV-based precision agriculture cycle

Retrieved from: (Raj R. , Kar, Nandan, & Jagarlapudi, UAV-based sensors in precision agriculture, 2020)



Appendix B: an overview of the technology readiness level scale

Retrieved from: (Mankins, 2009)



Appendix C: Satellite data vs. drone-based sensing

Retrieved from: (Raj R. , Kar, Nandan, & Jagarlapudi, 2020)

Table 2.1 Satellite data vs drone-based sensing

Sub-meter resolution commercial satellite image	Drone-based high-resolution image
Cloud cover and atmospheric dust particles create a bottleneck on image acquisition	As flight height is low thus limited effect of cloud cover
Real-time image acquisition and processing are not possible and usually take 7 days of delay	Images can be obtained and processed in a few hours depending on the size of the farm
Images captured at some fixed time of day depending on the frequency of revolution of the satellite	Images can be captured at the desired time of day
Maximum available panchromatic geometrical resolution is 30 cm, while multispectral resolution would be 1.24 m	Spatial resolution may go around 1 cm
Minimum area map which can be ordered is 25 square km or more (if only natural color map is required, then 10 square km)	Map can be generated for a small and medium area which would be much cheaper than satellite imaging
Images generally are taken from zenith	Images at a different angle can be taken which will help in getting architectural information of canopies

Appendix D: Protocol survey participants

Introduction

The United Nations expects the world's population to rise to 9.7 billion by the year 2050. This causes agricultural production to rise by 69% between 2010 and 2050. Which of course asks a lot from the farmers and makes them more important than ever. To meet this demand, farmers and agricultural businesses are heading more and more towards the usage of the Internet of Things for analytics and greater production capacity. Part of this is precision agriculture. Which can be defined as a management strategy that gathers, processes, and analyzes temporal, spatial, and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability, and sustainability of agricultural production. For the capturing of these data, drones can be used. The Association for Unmanned Vehicle Systems International has even stated that 80% of UAVs will be used for agricultural purposes in the near future. But the question is still, how ready are drones to fully function on the field?

Research

This research focusses on answering the question of how mature the application of drones in the precision agriculture field is and what is still needed to develop this further. The study will focus on drones operating in Europe, and drones that are sensing and moving. So, the drones that act upon gathered data will be left out. Unique about this research is that it will not only test the technology readiness. But will also test matureness on the business, ethical, legal, and social levels. To achieve the wanted results, a survey will be filled in by farmers, experts, and drone companies working in the agricultural field. Out of the collected data, a conclusion can be formed about how mature the drones in precision agriculture are. This will be done by analyzing the data together with an expert. A sub-goal of this research is to evaluate the tool used. By doing this, improvement points can be created on what Space 53 needs to improve in the Quick Scan Tool.

EFRO / SPACE 53 scan Tool

After giving some more background information we now come to the scan tool (survey) that will be used for the conduction of this research. I want to thank you in advance for participating in this research and helping me to gather as much data as possible.

By going to the next page, you will reach the survey that I would like to ask you to fill in. The survey consists of five different tools representing the five different dimensions. You as a participant can choose yourself with which tool you want to start and continue. By filling in the questions, please keep in mind the sector as a whole. So even if you are not able to purchase a drone yourself, keep in mind if it is possible for the sector. After filling in the five different tools, you can go to the end of the tool. Here, I would like to ask you to grade the different tools, so that this can be used to improve the tool. In the end, it is possible to download your results and answers.

Good luck with filling in the survey and thank you in advance!
Annelot Schmeitz.

Appendix E: Interview Guide

Introduction:

Hello and thank you for participating in this research and making time to take the interview!
First, I would like to ask you if I have permission to record the interview?

Some more background information. I'm Annelot Schmeitz and I study international business administration at the University of Twente. For my bachelor thesis, I'm researching the usage of drones in precision agriculture. This research aims to examine the maturity of drone usage in precision agriculture while using different dimensions and what implications there are for its development. A research question has been formed to help answer the aim;

- *How mature is the application of drones in the precision agriculture field and what is needed to develop this further?*

To get an insight into how mature the drone application in precision agriculture is at the moment, data is collected by the usage of a tool developed by Space3/EFRO. Here, the maturity is tested on five different levels, namely: technology; business; ethical; legal; and social.

The goal of this interview is to analyze the data collected and to get a better insight into what still needs to be developed to reach a higher level of maturity.
The interview is going to be a semi-structured, open question interview. The questions are related to the collected data and will be structured according to the five different dimensions.

Questions

Background

- Can you tell me a bit more about what your job is?
- And what is your expertise?

Technology

- How do you interpret the technology results?
- How do you explain the technology readiness level being so high?
- Where do you think technical improvement is still possible?

Business

- How do you interpret the business results?
- Why do you think that the financial level is so low? Since it's only 3,22.
- What could be a reason for the business readiness being so low?

Ethical

- How do you interpret the ethical results?
- Do you agree with the estimation of the participants?

Legal

- How do you interpret the legal results?
- Could you explain the big difference between the data protection level and the other categories?
    - Do you agree with the high score on data protection?
- Do you foresee an improvement in the legal aspects shortly? How?

Social

- How do you interpret the social results?
- Could you explain why the social readiness level is the lowest of all dimensions?
    - Since the results mean that the drone technology is not market-ready
- What change has to be implemented to have a higher acceptance of drones?

Connecting the different dimensions

- Could the low readiness level of business be influenced by the low readiness levels of ethical, legal, and social?
- Finally, do you feel like the sector is ready for drone implementation?

Thank you for your participation!