QuantiFarm

D1.1: Behavioural Determinants for DAT Adoption - first version

quantifarm.eu

D1.1: Behavioural Determinants for DAT Adoption - first version

Acronym	QuantiFarm
Full title	Assessing the impact of digital technology solutions in agriculture in real-life conditions
G.A. No.	101059700
Topic	HORIZON-CL6-2021-GOVERNANCE-01
Type of action	Research and Innovation Actions
Start date of project	1st July 2022
Duration	42 months
Author(s)/Organisation(s)	Caroline van der Weerdt, Shanna Wemmers, Sabine Verdult, Julia Broderick – Hale / TNO
Contributor(s)	Diogo Moniz / Consulai, Anja Langefeld / TNO
Peer-Reviewers	Nikos Kalatzis / NP, Francesco Parigi / POLIMI
Work Package	WP1 – Behaviour Innovation & Stakeholder engagement
Delivery Date (DoA)	M12
Actual Delivery Date	30/06/2022
Dissemination Level	R: PU: Public Usage
Abstract:	This report describes the research activities and outcomes of the behavioural work in QuantiFarm. Test Case farm visits, surveys amongst QuantiFarm DAT adopters and non-adopters, and a specific research into non-DAT-adoption were undertaken, resulting in an integrated framework of DAT adoption (outlining both the decision path of DAT adoption and related behavioural determinants). Lastly, farmer stories are created to vivify the found data.

Document Revision History			
Date	**Version**	**Author/Contributor/ Reviewer**	**Summary of main changes**
01/06/2023	1st draft	TNO	1st version
21/06/2023	2nd draft	Polimi, NP	Pre-final version for peer-review
28/06/2023	Final	TNO	Final version addressing all comments from peer-reviewers

QuantiFarm Consortium			
Participant Number	Participant organisation name	Short name	Country
1	GAIA EPICHEIREIN ANONYMI ETAIREIA PSIFIAKON YPIRESION (GAIA)	GAIA	GR
2	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO	TNO	NL
3	POLITECNICO DI MILANO	POLIMI	IT
4	NEUROPUBLIC AE PLIROFORIKIS & EPIKOINONION	NP	GR
5	CONSULAI, CONSULTORIA AGROINDUSTRIAL LDA	CONSULAI	PT
6	CONFEDERAZIONE GENERALE DELL AGRICOLTURA ITALIANA	CONFAGRICOLTURA	IT
7	FOODSCALE HUB GREECE ASSOCIATION FOR ENTREPREUNERSHIP AND INNOVATION ASTIKI MI KERDOSKOPIKI ETAIREIA	FSH	GR
8	PETERSON PROJECTS BV	PETERSON	NL
9	LUONNONVARAKESKUS	LUKE	FI
10	GEOPONIKO PANEPISTIMION ATHINON	AUA	GR
11	OKYS LTD	OKYS	BG
12	COMITE DES ORGANISATIONS PROFESSIONNELLES AGRICOLE DE L UNION EUROPEENNE COPA ASSOCIATION DE FAIT	COPACOGECA	BE
13	COMITE EUROPEEN DES GROUPEMENTS DE CONSTRUCTEURS DU MACHINISME AGRICOLE	CEMA	BE
14	. TEAGASC - AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY	TEAGASC	IE
15	INSTITUTO TECNOLOGICO AGRARIO DE CASTILLA Y LEON	ITACyL	ES
16	HORTA SRL	HORTA	IT
17	KATHOLIEKE UNIVERSITEIT LEUVEN	KUL	BE
18	DELPHY BV	DELPHY	NL
19	INSTITUT DE L'ELEVAGE	IDELE	FR
20	AUGMENTA AGRICULTURE TECHNOLOGIES MONOPROSOPI IDIOTIKI KEFALAIOUCHIKI ETAIREIA	AUGMENTA	GR
21	ASOCIATIA NATIONALA A INDUSTRIILORDE MORARIT SI PANIFICATIE DIN ROMANIA	ANAMOB	RO
22	UAB ART21	ART21	LT
23	AGROSMART SIA	AgroSmart	LV
24	BENCO BALTIC DOO ZA SAVJETOVANJE IUSLUGE	BENCO	HR
25	FARM FRITES POLAND DWA SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA	FFP2	PL
26	AGROMAIS PLUS COMERCIO E SERVICOSAGRICOLAS S.A.	AGROMAIS	PT
27	KMETIJSKO GOZDARSKA ZBORNICA SLOVENIJE KMETIJSKO GOZDARSKI ZAVOD MURSKA SOBOT	KGZS	SI
28	TERRA LITTERA DO0	Terra	RS
29	ANYSOLUTION SL	AnySol	ES
30	A.M. FILAGROTIKI SYMVOULEFTIKI LTD	Filagro	CY
31	AGRIDEA SCHWEIZERISCHE VEREINIGUNG	AGRIDEA	CH
32	FLOX limited	FLOX	UK

LEGAL NOTICE

Funded by the European Union under Grant Agreement No 101059700. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

Funded by
the European Union

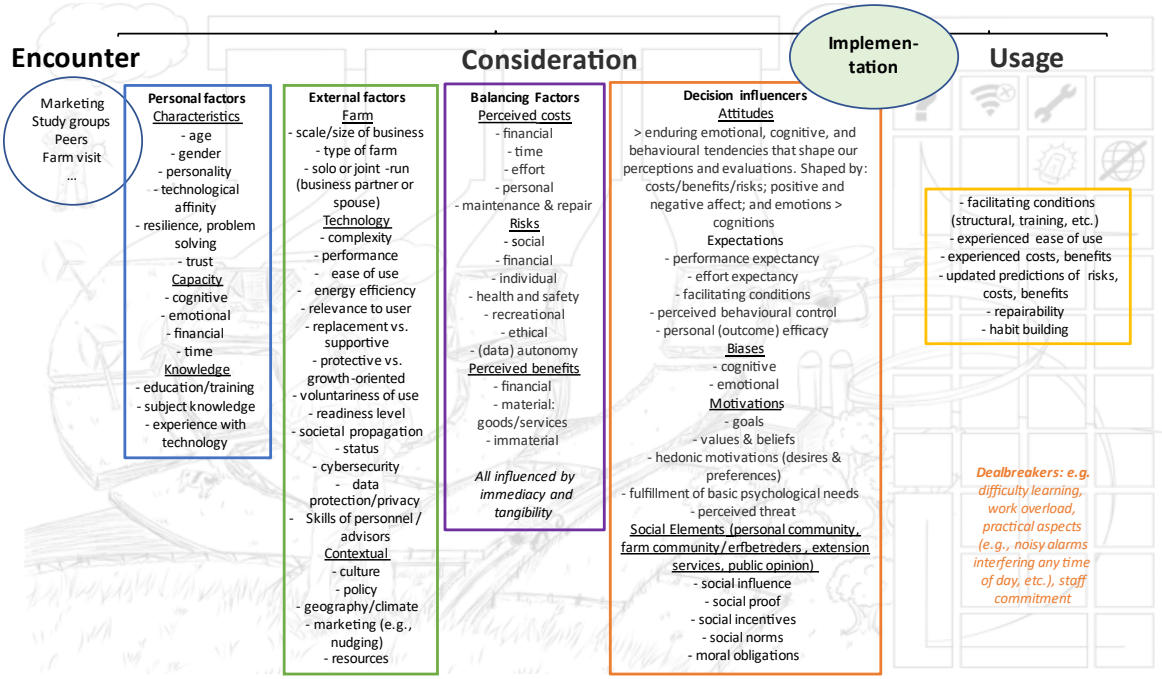
Executive summary

Fundamental to pursuing an effective strategy of scaling up DAT usage amongst the European farming population to reach sustainable goals, is to understand how farmers' behaviour interacts with these DATs, and how true adoption of them in the farming operation comes about. Coming to this understanding is the goal of Work Package 1, followed by translation this into guidelines for others on how to then support farmers in the best way to make decisions on whether or not to adopt (a) DAT(s) on their farm.

The first year of QuantiFarm's Work Package 1, which is now behind us, focused on building a solid research body around the behavioural determinants of DAT adoption. To this end, several activities were undertaken:

- A broad literature study on technology adoption, DAT adoption, and farmer decision-making;
- Test Case farm visits to 9 of the 30 QuantiFarm Test Cases;
- 2 surveys amongst the whole Test Case population, one for DAT adopters and for DAT non-adopters;
- And a separate study on non-adoption outside of the QuantiFarm population, to gain more understanding of our wider audience.
- All our research findings together, resulted in a novel framework that connects both the adoption process of DATs with the determinants present during this process (please note that this framework is elaborated upon in chapter 4 of this deliverable):

QuantiFarm integrated DAT adoption framework



To make this collection of data come alive, several farmer stories have been created of anonymous archetypes (generalised representations of farmers, with certain contexts and traits), yet very much relatable to the findings of the Test Case visits, surveys and extra non-adoption research. These stories portray several specific situations, that can be traced back to the determinants in the integrated framework, from different farms and family contexts, to attitudes, worries, motivations and experiences: a story on securing the farm legacy through digitalisation; a story more on digital autonomy; the story

of an ardent and prudent pig farmer; a story of farmer with a keen business mentality; and a farmer in doubt about digitalisation.

With all the data collected so far, this deliverable is intended to serve as a reference work for coming (research) activities and the development of comprehensible guidelines for all partners and stakeholders united in their ambition to support farmers in their decision-making process and adoption of DATs.

Table of Contents

Table of figures

1. Introduction

1.1. Project summary

The QuantiFarm project focuses on supporting the further development of Digital Agriculture Technologies (DATs) as a key factor for improving the sustainability performance (economic, environmental and social) and competitiveness of the agricultural sector. To this end, QuantiFarm introduces a comprehensive Assessment Framework for independent qualitative and quantitative assessments of the multiple costs and benefits of digital agriculture technologies. Ensuring replicability and uptake of digital technologies by deploying innovative tools, services, recommendations and making them relevant and of practical use to farmers, advisors, and policy makers across Europe. QuantiFarm is building the project activities around 30 Test Cases (TCs) which span over 20 countries in 10 Biogeographical regions across Europe, capturing multiple geo-political and financial settings. More than 100 farms of different types, sizes, ownership and operating conditions, committed to participate in the project, both directly but also through cooperatives and large umbrella organisations. The TCs actively engage farmers, advisors, DIHs, researchers/scientists, DATs providers, certification experts and policy makers. Moreover, QuantiFarm Digital Innovation Academy will be established as the main capacity building mechanism for advisors and other AKIS actors on the various types of digital technologies available, their costs, benefits and impact on sustainability and will offer training sessions for advisors. QuantiFarm comprises 32 partners, representing all relevant stakeholders, including 8 scientific organisations and 12 farmer representatives and consultants.

1.2. Document scope

Central in Work Package 1 (WP1) is the identification of determinants of Digital Agricultural Technology (DAT) adoption in agricultural practices, in order to understand why and how DATs are adopted with different farmers in different contexts, and the accompanying decision-making process.

Material and immaterial drivers, short and long term goals, and attitude towards technology: these are just some of many factors -to be elaborated upon on more in chapter 3- that may play a (key) role in how a farm is perceived and managed (e.g. Huang et al., 2010; Van Velthoven, 2012; Mankad, 2016; The farming podcast, 2018; Boerenverstand, 2021, etc.). These factors can partially be explained on a generic level, but may also differ per farmer. For instance, as for some farmers the “love for their job” and “being outside” is central to their identity as a farmer, for some it is the opportunity to create an “optimal business”, that can be ‘scaled up sustainably, supported by relevant technology’ (these are insights from interactions with Test Cases in the first year of the project). The range and impact of such behavioural factors influences DAT adoption. In the end, this knowledge of DAT adoption is fundamental to develop behaviour intervention recommendations that can enhance DAT uptake; a main goal of the QuantiFarm project.

To collect the needed insights, during the first year of QuantiFarm different types of research have been conducted in WP1, which are further explained in chapter 2. As a consequence, a year into the project, already many relevant findings have been recorded on behavioural aspects in DAT adoption. These findings have been integrated with the findings on farmers’ decision-making processes, both leading to the integrated QuantiFarm framework of DAT adoption. This framework helps to recognise specific ‘threads’, here called ‘farmer stories’, describing how, step by step, DAT adoption comes about. Besides reporting on all the findings, this deliverable presents the initial versions of the framework and the farmer stories. In sum, the scope of this deliverable is to conjugate all the findings from the behavioural research in QuantiFarm so far, to serve as a reference work for further activities.

A next step for WP1 is to translate the findings, together with stakeholders, into guidelines for creating interventions in such a way that DAT uptake in the EU can be supported, from how tooling is being set-up (in cooperation with WP3), to how policy makers can design scaling programs (in cooperation with WP5). A means to enhance the dialogue with stakeholders, the farmer stories will be turned into vivid storyboards that illustrate the findings in a way that helps to emphasise with the situation of different farmers (an example of such a storyboard can be found in appendix D).

1.3. Document structure

This document is comprised of the following chapters:

Chapter 1 presents an introduction to the project and the document.

Chapter 2 describes the research approach, followed by a literature review on known determinants of technology adoption and agriculture-related technology adoption (as this body of work has guided the initial steps in WP1).

Chapter 3 outlines the determinants found in the QuantiFarm project itself so far will be outlined, per research activity. This includes determinants based on Test Case visits and surveys.

Chapter 4 goes into the resulting ”integrated framework of DAT adoption” in which all found determinants are comprehensively clustered.

Chapter 5 introduces consequent stories of farmers that connect these determinants to actual decision-making and practices on the farm, to vivify the found data.

Chapter 6 presents conclusions and further steps are proposed.

Chapter 7 contains the overview references we utilised in the research process

Chapter 8 lastly contains appendices for background information in the content

2. Approach

2.1. Research approach in QuantiFarm

An important driver for how the activities in WP1 have been designed, was the awareness that earlier research on DAT adoption or related, was albeit being very relevant, often based on either questionnaires or structured interviews (e.g. this is the case in many of the references of chapter 7). This inherently leave less room for spontaneous observations. In fact, directly asking about one's behavioural drivers is prone to lead to suboptimal insights, as this is often hard for people to express. Therefore, to genuinely grasp as much factors influencing DAT adoption as we could, we chose to employ a more observatory approach first. This was then followed by surveys, to get a feel for which findings from the observatory study we could generalise for the wider population.

In a few other ways, QuantiFarm also adds to the existing knowledge base of previous research on DATs:

- Concerning the objective and design of the project:
  - The objective is to support the further deployment of those DATs that add to the sustainability of the agricultural sector;
  - The QuantiFarm Test Cases vary a lot in their context and the digital technology applied (e.g. DSS, robotics) making it possible to compare several situations;
  - QuantiFarm is a multi-year project, which gives the behavioural research work the outstanding opportunity to study variations in (behavioural) dynamics over time;
- Concerning the objective and design of the behavioural work in the project:
  - Following from the above, the ultimate goal of the behavioural research in QuantiFarm is to inform stakeholders on ways to optimise the adoption of truly sustainable digital agricultural technologies;
  - By adoption we chose to follow a definition tailored to the QuantiFarm project: adoption of a DAT in our case means the DAT is applied in the daily and/or cyclical farming practice, as part of the farmer toolset to undertake sustainability-oriented operational and/or managerial practices;
  - Our focus is also on decision-making and adoption as a process over time, as we know that adopting a DAT is not a binary yes/no decision, but rather influenced and shaped by many factors during a longer time span;
  - And lastly, we add specific views on non-adoption to deepen the understanding of DAT adoption sharpen results;
  - And lastly, to be effective in our outcomes, we take a targeted approach to identify those enablers that can be scaled; and the barriers that can be overcome.

Our approach to gain the insights specific to QuantiFarm is comprised of a combination of literature research, Test Case farm visits, surveys and workshops. With this mixed method research we aimed to collect a wide spectrum of data, allowing us to find patterns in farmers' decision-making around DAT adoption. Below, all steps in our approach are described shortly.

2.1.1. Literature study

Good practice in the research domain is to scan the literature that is already available, and that either contains directly applicable data, or can inspire ways to collect new data. A literature study also prevents too much overlap between research thereby ensuring that the current research truly adds to what is already there. Therefore, WP1 started with a literature study at the beginning of the project. However, the integration of existing research remains a basic activity, even in the upcoming stages of the project, so this will be continued whenever relevant.

The main outcomes of our literature study are described in this chapter (paragraph 2.2). In the third chapter we consequently add all the findings from the QuantiFarm project itself.

2.1.2. Test Case farm visits

Central to QuantiFarm are the farm visits undertaken to the Test Case (TC) farms, and farmers, of the project. Conducting field visits helps to truly engage with farmers, ensuring a dialogue can take place in a trusted environment and thereby increasing the chances that real stories of adoption (with uncertainties, attitudes, etc) are being expressed. Also, it gives researchers a better understanding of the context that farmer decision-making takes place in. The research team employed "participatory observation" (Sirris et al., 2022) during the field visits, which means a researcher observes a participant, in this case a farmer, during longer stretches of time during his or her daily activities, simultaneously exchanging on what is going on and why.

After walking the field and visiting the premises, the researchers and farmer (and others present, such as the advisor or TC manager) continued to a different location for a semi-structured interview. Ideally this was held at their home or canteen. This way a safe setting could be created to speak freely, and also get an idea of the more informal processes on the farm, the habits, and family influences, which all contribute to how innovations find their way onto farms. The entire visits usually lasted a couple of hours and without exception the researchers felt cordially received and were given a thorough insight into daily farm practice.

The researchers recorded the main aspects of the field visit by taking notes and pictures; interviews in turn were recorded via notes and sometimes audio recordings. Reports per TC (with photos, a short recap and main insights / take-aways) are available in a separate document: "Report on Test Case farm visits M1-M12". In this deliverable the aggregated findings are elaborated upon in chapter 3.1.

2.1.3. Surveys

Given the goal of the project to support the uptake of DATs Europe-wide, a logical next step in the research is to gather the surfaced insights from the individual visits and have them reflect upon by a larger population. The survey conducted in April of 2023, targeted towards all the adopter TC farmers that are deploying the DAT under assessment in the project and have a say in the decision-making, was aimed to do just that. The survey consisted of a few components: open questions to distil the respondents' own stories (e.g. by reflecting on two anonymised TC farm visit stories); prioritising determinants, and indicating how the relationship with the DAT on the farm is perceived. The whole survey can be found in appendix A. The survey was filled in by 24 Test Cases and 40 farmers (some TCs have more farmers working with the DAT who responded to the survey).

End of May / beginning of June of 2023, this survey was followed by a largely comparable survey, this time specifically targeted towards the so-called non-adopter farmers linked to the TCs that do not deploy the assessed DAT. The goal of this survey was to find out where significant behavioural differences can be distinguished between the two groups. This helps to both deepen the understanding of the dynamics, and ensures that consequent steps, such as the development of guidelines, are even more fine-tuned. In the end, 15 out of 30 TCs responded to this non-adopter survey, with 17 respondents in total (2 TCs had 2 respondents).

2.1.4. Additional research non-adopters

Lastly, for even broader coverage, we also turned our scope to farmers outside of the QuantiFarm project who are not (yet) adopters of DATs, as they are in the end a target audience for the project outcomes. We did that in cooperation with the Dutch branch of the Slow Food Youth Network (SFYN[1]). SFYN stems from the Slow Food movement, an organisation with communities worldwide to "prevent

1 More information about SFYN: https://www.slowfood.com/about-us/

the disappearance of local food cultures and traditions" as a counteract on "fast food". The Slow Food movement aims to ensure everyone has access to "good, clean and fair food". The related SFYN Academy works with a selection of 26 experts studying or working within the foodchain who follow a half-year program. During this time, themes such as culture, politics, agricultural technologies and the environment and their effect on the food chain are researched, taking into account the whole chain from production to consumer. SFYN's additional research has added value in two ways. First, the process and methodology brought insights into useful research approaches, making it possible to evaluate what method of research works for this target group and context. Second, the outcomes of the research gave a first glance and better understanding of non-adopters, not involved in the project but certainly a target group of the project, in the Netherlands. The research approach itself is described in detail in appendix C. The outcomes can be found in chapter 3.3.

2.2. Overview of literature research outcomes

As the attention for digital technologies to support sustainable innovations in agriculture grows, so has the amount of research on the dynamics around their adoption (e.g. Rose, et al., 2016; Barnesa et al., 2019). Technology adoption in general has already been researched for many decades, with models being continuously refined based on new insights (e.g. Davis, 1989; Venkatesh, et al., 2003). This makes that QuantiFarm has a great body of work to start with for understanding behavioural determinants in our current practice. Adoption of agricultural technology however, even more specifically digital technology in agriculture, can be regarded as a subsection of these more general frameworks, and as a result has been researched less than general technology adoption. In the following paragraphs, we report on the main findings of the literature research, for both generic and agricultural technology adoption[2].

2.2.1. General technology acceptance

In order for technology to be adopted, acceptance of it by the intended user of the technology is key. When and how people accept technology has been researched extensively, leading to multiple technology acceptance/adoption models, some of them comprehensively put together by Taherdoost (2018) who aimed to support information system developers with this overview (see figure 1 below). Rather well-known examples included in the overview are the Technology Acceptance Model (Davis, 1986; Davis, 1989; Davis, Bagozzi & Warshaw, 1989); the Theory of Planned Behavior (Ajzen, 1985); the Diffusion of Innovation theory (Rogers, 2003); the Theory of Reasoned Action (Fishbein & Ajzen, 1975), Model of PC Utilization (Thompson, et al., 1991); and the Unified Theory of Acceptance and Use of Technology or UTUAT (Venkatesh, et al., 2003).

2 Not all studied documents are reported here; for the entire overview, please contact the authors

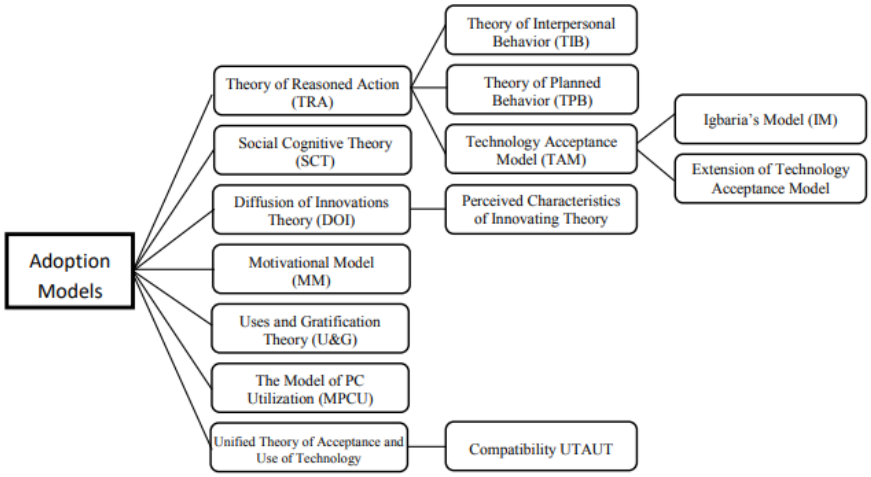


Figure 1: Adoption model overview (Taherdoost, 2018)

For the QuantiFarm research the latter one, the UTAUT framework, was employed as a starting point, as this model in itself is unification of different models that incorporate aspects that are estimated to be relevant in DAT adoption, too, such as social influences. We will thus elaborate a bit more on UTUAT below.

2.2.2. Unified Theory of Acceptance and Use of Technology (UTUAT)

UTAUT identifies four key factors that can influence the intention to use technology, and therefore actual use:

- Performance expectancy: this refers to the extent to which an individual believes that using a technology will help them to perform their job or task more effectively or efficiently. This can be influenced by factors such as the perceived usefulness of the technology and the extent to which it aligns with the individual's goals and needs.
- Effort expectancy: this refers to the perceived ease of use of the technology. This can be influenced by factors such as the perceived complexity, the level of user support and training available, and the individual's prior experience with similar technologies.
- Social influence: social influence refers to the extent to which an individual is influenced by the opinions and behaviours of others when deciding whether to adopt and use a technology. This can be influenced by factors such as the perceived norms of the individual's peers or colleagues, and the extent to which the individual values social acceptance and approval.
- Facilitating conditions: these refer to the external factors that can either facilitate or hinder the use of technology. These can include factors such as the availability of resources and infrastructure, organisational policies and culture, and regulatory frameworks.

The UTAUT model also recognises that individual differences can influence technology acceptance and use, such as gender, age, and experience. Additionally, the model suggests that the relationship between intention to use and actual use may be influenced by other variables, such as external barriers and constraints (Venkatesh, et al., 2003).

2.2.3. Agricultural technology acceptance

Although it is comprehensive and rather complete, UTUAT is a general adoption model whereas we are most interested in digital technology adoption in agriculture. Our literature study has therefore also

focused on existing research on DAT adoption. In the literature, we roughly distinguish a difference between precision-related technologies, and decision-support systems.

2.2.4. Adoption of precision agricultural technologies

Precision agricultural technologies (PATs) ensure "plants (or animals) get precisely the treatment they need, determined with great accuracy"[3]. From previous research (e.g. Barnesa et al., 2019) we find that farmer attitudes towards precision technology can differ: non-adopters without adoptive intention, often perceive that the technology takes too long to see a return on their investment, and the upfront costs are perceived as too high. Farmers who did adopt PATs, but do not wish to invest further, are predominantly uncertain of the outcomes and how effective they truly are. Evaluation of the benefits and payback is extra complicated by the diverse application areas and geographical contexts of PATs. Next to the financial considerations, a PAT may challenge ecological-identity principles of some farmers: as PATs are mostly known to support systems focused on intensive farming, this may create a barrier for farmers who could benefit from them, but are highly reluctant to compromise on their attitude and image as an ecological farmer (Barnesa et al., 2019). Specifically in the context of organic farmers, this finding has also been confirmed by Naspetti et al. (2016); organic farmers are motivated first by environmental concerns, and by (other) economic concerns secondarily. They demonstrate a desire to produce healthy products and avoid chemical use, motivated mainly by protecting the environment, and will make their adoption decisions accordingly.

Also age, education, scale of agricultural area, income, farm specialisation, and current farm technologies play a role in the adoption of PATs, at least in the five European countries this same research was conducted (UK, Germany, The Netherlands, Belgium and Greece). Younger, higher-educated farmers managing larger agricultural areas with higher incomes, are indeed more likely to adopt PATs, compared to older and lesser ("informally") educated farmers, as found by other research (e.g. Schimmelpfennig, 2016; Miller et al., 2017). Furthermore, labour seems to play a role: adopters have more regular employees (Paustian and Theuvsen, 2016), while unpaid farm labour, such as family, may actually slow down the adoption (Schemmelpfenning, 2016), perhaps because of the unwillingness to break with the family traditions. There are also signs that owner-occupied farmers are more likely to adopt, due to access to capital for machine investment (Paustian and Theuvsen, 2016). And, when a farmer has access to support, advice and/or information from peers, this will positively influence PAT adoption by reducing uncertainties (Miller et al., 2017).

PATs are now usually considered to be an extra pair of eyes. However, PATs do have the potential to accelerate so-called smart farming, where precision technologies not only secure access to (real-time) information, but also play a key role in the decision-making. To get to this point though, the PATs need to be quicker than manual labour; more energy efficient; and be supported by better internet (Moysiadis et al., 2021).

Other research has turned attention to more psychologically-driven adoption determinants that are not necessarily focused on PATs or DATs, but more on sustainable farming measures in general that are worth mentioning. For instance, fulfilment of basic psychological needs (e.g. safety, security, good health, feeling socially connected) motivates farmers' implementation of sustainable measures (Meierová and Chvátalová, 2022). In other words, if these are not in place, it is hard to consider investing in new solutions. But also, farmers adopt new practices when they perceive clear and tangible financial and practical benefits. Why? Because farmers contend with complex daily decisions that consume their attention and emotional capacity, leaving limited cognitive capacity for decisions that seem less urgent, such as considering to implement something new (Mankad, 2016).

[3] https://www.wur.nl/en/Dossiers/file/dossier-precision-agriculture.htm

2.2.5. Decision Support Tools use in Agriculture

The use of decision support tools on the farm are aimed to give farmers evidence-based guidance in their farming decisions. Often, they are targeted towards supporting productivity and making financial decisions, but more and more they focus on supporting with sustainable/environmental decision-making. In many cases in fact these go hand in hand (e.g. when decision-support is given on minimising the use of inputs).

The Theory of Uptake and Use of Digital Support Tools (DSTs) in agriculture (Rose, et al., 2016) has proven to be a useful tool for understanding the adoption and application of digital technologies in agricultural contexts, and has therefore also inspired our research. It is largely comparable to the earlier-mentioned UTAUT model, but the main difference is their scope, where the DST model focuses on the agricultural context. Furthermore, the DST model does acknowledge the UTUAT factors of expectations (on performance and ease of use), social influences and facilitating conditions, but it also highlights the critical role of technology characteristics and external factors, such as policy and regulatory frameworks, in influencing the successful adoption and use of DSTs. Interestingly, as the model clearly distinguishes between uptake and actual use of the decision-support tool, it is only the factor of "compliance" (e.g. to legislative measures) that will directly influence use, as most other factors will influence uptake, but not necessarily (proper) usage. This difference between uptake and use is a relevant distinction we will also incorporate in our further work.

The DST model also mentions the importance of the trust, and compatibility between the farm advisor and the farmer as determinants of adoption, which acknowledges the fact that many decisions of farmers take place in agreement with other trusted parties, not in the least decisions on new investing in new technologies. Lastly, the model by Rose et al. (2016), illustrated in Figure 2, points out how the marketing of digital support tools is actually a driving factor of the uptake of them.

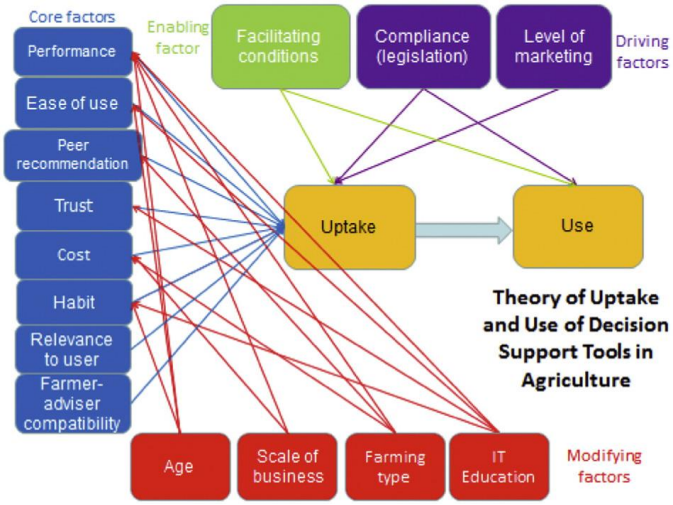


Figure 2 Theory of uptake and use of DST in agriculture. From Rose et al. (2016)

2.2.6. Digital agricultural technology adoption

As we have already concluded that DAT adoption is not a binary yes/no decision taking place in isolation, an important objective for WP1 is to capture farmers' experience of DAT adoption from start to finish. Such a broad scope is crucial to align with the mission of QuantiFarm, which follows farmers and measures experience over time. Support for this perspective has been found in the literature, where it is recognised that technological change is not a simple, linear, dichotomous switch but rather a

complex, interactive process situated within a broader context. Glover et al. (2019) put forth a framework to capture this complexity, characterising technology change in four components that may be placed on a decision-timeline: first, what are the key elements of the proposition, or the technological solution on offer; then, in what way can a farmer encounter the technology; next, how does this encounter and the proposition itself shape the dispositions of the farmer and the disposition of the farmer's social context such as the family (attitude, perceptions, uncertainties, etc) towards the technology; and, lastly, how does a farmer then in fact respond (i.e. is there a willingness to try it out and what happens during the trial; is there a refusal altogether, or immediate enthusiasm to implement?). Of course, this is not yet the complete story. Even after the DAT has reached the stage that it is actually implemented, still a lot can take place, or in fact, go wrong. For instance, decision-support tools can be used in a different way than originally intended: e.g. at what moment they are used; which applications are used; and how the given data is interpreted. This can lead to suboptimal use of the tools and thus sub-optimal results (Glover, 2019).

Resulting from all of the above, we can safely say that the determinants of DAT adoption vary greatly, and the implications of how farmers actually come to a choice to invest in DATs and use them effectively is a domain to explore further. In the following chapter, we add to this body of research with the results of our own research in the QuantiFarm context.

3. Determinants of DAT adoption in QuantiFarm

In this chapter, we outline the findings from the behavioural research conducted in the project itself: the Test Case farm visits; the survey among the broader group of adopter and non-adopter TC farmers, and the non-adopter research in the Netherlands.

3.1. Outcomes Test Case farm visits

During the period of June 2022 up and until June 2023, 9 test cases have been visited. For every farm visit the following was reported:

- Date and location;
- Name and type of farm;
- Summary of the visit;
- Reflection on the visit and main take-aways;
- A few photos;
- Main farmer characteristics;
- And contextual factors, relating to the country or area the farm is located in.

The visits have taken place at the following Test Cases (in chronological order of the actual date of the visit):

Date of visit	Country	TC #	Official TC name (incl farm type + technology)
25/09/2022	Portugal	2	Precision Irrigation for corn in continental region
03/10/2022	Italy	13	SF DSS/ App for Grapevine in Continental region
21/11/2022	The Netherlands	6	Machinery with VRA, data analytics for wheat, onion and potato in Continental region
22/11/2022	The Netherlands	16	Drones and soil sensors for Apples in Continental Region
22/11/2022	Belgium	24	Automated monitoring for pigs in continental region
23/11/2022	Belgium	24(a)	Pig Farm PROOF
15/03/2023	Croatia	30	Sensors for quality assessment for oyster in Mediterranean region
28/03/2023	Germany	27	Automated monitoring for cows in Continental region
18/04/2023	Greece	4	VRA add-on for old tractors for cotton in Mediterranean region

Figure 3 List of Test Case farm visits

The background as well as the farm type of the farmers ranges from family businesses to entrepreneurial new enterprises, in different climatic regions and cultural settings. Without exception, the visited farmers believe that the DAT they utilise supports in their work. The perception of how much value the DAT adds varies somewhat though; whereas all agree the DAT is a welcome extra pair of eyes, some state the DAT is in fact indispensable for the farming operation. The Italian vineyard farmer (a male of around 30 years of age) for instance had no historical knowledge of the farm and used the DAT as a support system to bridge this information gap. The Dutch farmers (male, between 46 and 55 years of age) see the DAT mainly as a management decision tool that helps to validate decisions, whereas the Croatian (male, around 30 years old) and Portuguese (male, around 50 years old) farmers see the DAT as a necessity to secure or even grow their business, in parallel to making it more environmentally sustainable. More specifically, the Croatian sea food farmers see the DAT as a means to monitor and anticipate upon sea flows and currents affecting the oysters, and as a logging mechanism to learn from

operational mistakes (e.g. lifting the oysters too late). The Portuguese farmer sees his precision irrigation system as central to dealing with droughts, while it helps to counter the perceptions of how corn farming compromises on biodiversity; he observed an increasing number of bees on his fields since he uses precision farming. This is latter argument is also an example of how the DAT can also be used for marketing purposes. The Portuguese farmer furthermore stresses how DATs are his means to reduce business risks, as he knows precisely what to do where on his field and lowers his costs of inputs.

A shared view is that all farmers are passionately involved with the farm work (”being a farmer is a lifestyle not a profession” most farmers agree) but DATs help to shift the balance a bit of having to always be on the farm physically, and now being able to observe the farm remotely. This is true for arable and livestock farmers alike. The young German dairy farmer (male, around 30 years of age) now checks on his cows while relaxing on his couch, which makes all the difference. Moreover, he knows far more precisely which cow needs what because the sensors in their intestines. The Greek farmer (male, around 30 years of age) also pointed out that digitalisation, for the same reason of improved work-life balance and more precise insights, helps to make the profession of farming more attractive for younger farmers (although the older generations are often more sceptical). The targeted view on what needs to happen when and where, is a characteristic of DATs that is appreciated by all. The farmer, however, is still ultimately responsible for processing the DAT data towards action perspective.

Although regulatory frameworks greatly vary (which is remarked as a great barrier to DAT adoption), what is shared is the sense of pressure on the farming business to farm more sustainably, both on policy level and increasingly coming from public opinion. All farmers are acutely aware of climate change, so they are all contributing to more sustainable farming, but some feel the support for this (e.g. through subsidies) is chaotic and does not match investment timespans. The female pig farmer from Belgium (around 50 years of age) even feels subsidy schemes are a means to mend a broken market. Adding to this are the economic fluctuations; the market for most farmers is difficult as the prices the farmers get for their products can be below cost price, whilst input costs are going up.

Concluding, most farmers agree that their DAT adds value to their farm. Besides their inherent differences, they all share the experienced pressures on their farming profession.

A detailed report of all TC visits with photos can be found in the document “Report on Test Case farm visits M1-M12”, available upon request to the authors of this deliverable. More details about the DATs in the Test Cases can be found in The QuantiFarm Deliverable 4.1 Testing and Assessment Guidelines.

“*We don’t believe in no change*” – Test Case farmer in QuantiFarm

“I don’t want to receive subsidies; I want a healthy market” – Test Case farmer in QuantiFarm

“*Digital technologies reduce my business risks*” – Test Case farmer in QuantiFarm

3.2. Outcomes Surveys

3.2.1. Survey for DAT adopter farmers

All Test Case farmers that are deploying the DAT under assessment by the project, were approached to take part in a survey, regarding their DAT adoption. Surveys are a useful way to collect data amongst a broader population and test findings from the individual cases of the Test Case visits. The survey was web-based and sent to the Test Case farmers via de Test Case managers with a link per Test Case. As described in 2.1.3, the survey was conducted in April of 2023 and filled in by 40 farmers representing 24 Test Cases. It was available in different languages, upon request from the Test Case managers. As can be seen below, most participants preferred the English language (40%), followed by Greek (27%), Spanish (15%), Dutch (10%), Romanian and Swedish (both 3%), and Slovenian (2%). The survey itself can be found in Appendix A.

Please note that the respondents were, besides closed-answered questions, also asked to answer open questions. Remarkable quotes that support the data are added to this results overview. In the case these were originally written in a language other than English, we used Google Translate to translate them. The answers that already came back in English were left as such (including language mistakes), to prevent interpretation errors and, especially, to reflect the respondent's true words and opinion as much as possible.

As for the age range, almost half of the famer population is between 30 and 45 years old (47%), followed by an older category between 46 and 55 (29%), an older category over 56 years old (16%). The smallest group, with not even 10%, has the lowest age category from of below 30 years old (8%). The age is asked for descriptive purposes; not yet for statistical correlations as the dataset is limited. This may be done however when the survey is repeated at a later stage.

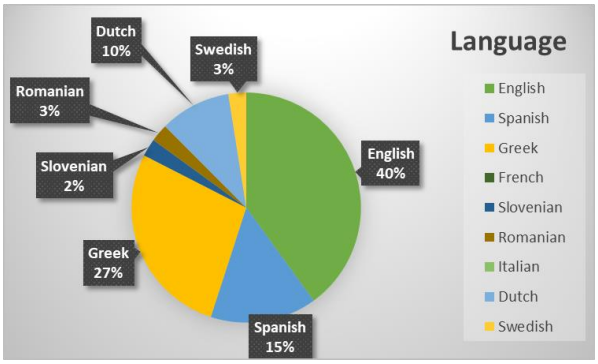


Figure 4: Preferred language

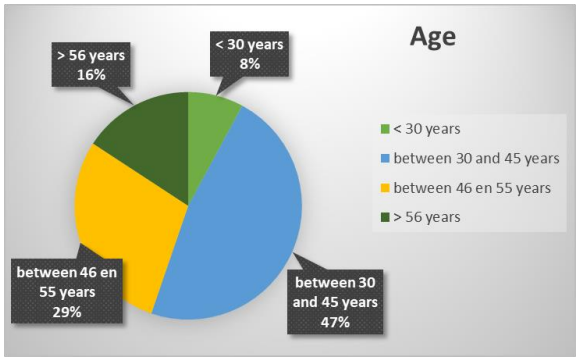


Figure 5: Age category

Next, farmers were asked to read stories and select the one they could identify most with. The stories were created specifically for the survey, yet they were based on the Test Case visits, summing up those findings in two distinct anonymous, yet relatable farmer stories; those of Peter and Kris.

Of the respondents, 79% (31 out of 40) feel most attracted by Peter's story. Mostly because they relate to the statement that digital resources have an added value for the farm.

Respondents who feel more attracted to Kris' story (21%) are a bit more diffused in their reason why. The story of Kris has several aspects in itself that can be addressed (concern for the future, running a B&B together with the spouse, specific opinion on DAT-use). Sometimes people chose Kris' story because "the future for small farmers is uncertain"; others because "the whole family is involved" (quotes from the respondents).

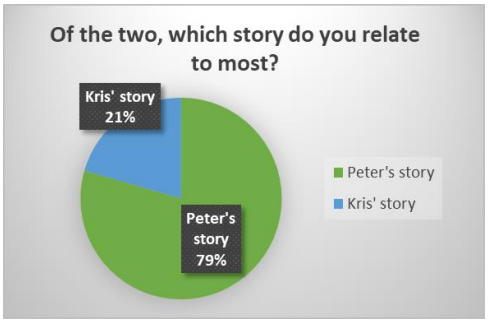


Figure 6: Most relatable farmer story

3.2.1.1. Farm size and succession

In order to paint a picture of the future prospect of the farm (i.e. if the farm has a successor), as this may influence investment decisions, the farmers are asked whether they have a succession plan in place. About half of the respondents (49%) does have a succession plan in place. Interestingly, almost all of them started doing this work themselves because they took over the farm from their father/family.

Age seems to play a role here: the older one is, the more likely it is that there is succession plan (please note however that this finding is not conclusive as the amount of respondents is relatively small).

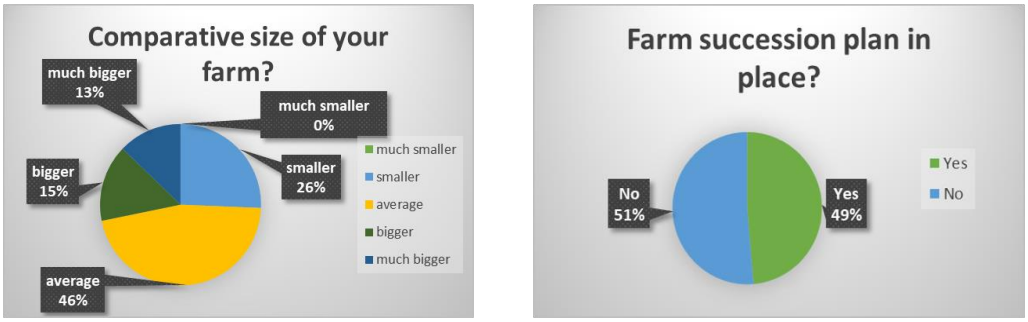


Figure 7: Farm size and succession

Next, we asked a few open questions to get a feel for personal motivations and values, in the farmer's own words. This helps to understand and give context to the other answers farmers give in the survey.

3.2.1.2. Why did you become a farmer?

Most respondents said something in the range of: family business, father to son, raised on farm/rural area, family tradition, outdoor living.

This also comes forth from the (literal) quotes:

"I liked it since I was little when I accompanied my father to do the work of the field"

"As the main economic activity of the area"

3.2.1.3. What are you most proud of as a farmer?

Frequently mentioned aspects that farmers are proud of: feeding people, production, product quality, sustainability.

This also comes forth from the open answers:

"From being a fundamental part in the value chain of a fundamental thing, feeding humanity trying to preserve the environment."

"belonging to a sector in contact with the earth and the environment."

"I am proud to use precision farming systems that are still new in my country and I am one of the first to use them."

3.2.1.4. What are your main concerns for your farm?

Respondents were then asked about their main concerns for their farm. They very often indicated the following concerns: climate change, changing rules, changing consumer opinions, prices (costs that production entails, and what the product yields).

The context behind these aspects can also be found in the following quotes:

"I'm always worried about the weather"

"The elimination of powerful pesticides and their non-replacement with equally effective ones results in the difficulty of dealing with the natural enemies of the crop."

"Climate change and prices."

"My biggest concern is the profitability of my farm. Since the factors of production are increasingly more expensive and the value of production cannot compensate for this difference."

"*If it will be able to remain profitable so that my son can live on it as I have done so far*"

3.2.1.5. Affinity with technology

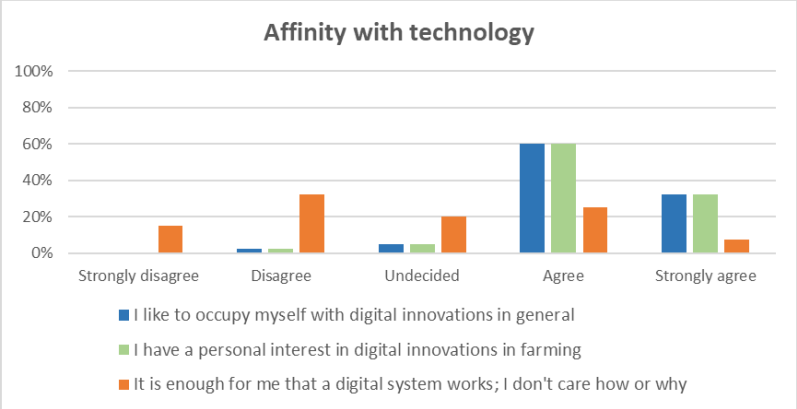


Figure 8: Technology affinity

To get an idea of whether our adopter farmers already have a positive predisposition towards technology, we used the official ATI (Affinity for Technology Interaction Scale) by Attig et al. (2017). From this, we see that the vast majority of the QuantiFarm DAT farmers is interested in digital innovations, both in general (93%) and in digital innovations in farming (83%). Another 48% also wants to know how or why a DAT works (just that it works is not enough); an indicator for a group that has indeed an affection towards technology itself, and something to take into account when applying our findings on a greater scale.

3.2.1.6. DAT investment and application

The biggest group invested in the DAT somehow, with 42% investing themselves and 10% together with others. Another substantial group of 38% does use the DAT, but did not financially invest in it themselves. Lastly, for 10% of the people other arrangements have been made.

Often the respondents are the ones that use the DAT the most (84%). The way respondents interpreted their time working with DAT was questioned over 4 tasks: analysing data (31%), decision making

(26%), collecting data (25%), and following instructions (18%). All 4 tasks require a substantial part of the time spent on the DAT. It is possible that with more experience working with the DAT (and confidence that the DAT works well) a reduction in time in analysing and interpreting and making data-driven decisions is possible.

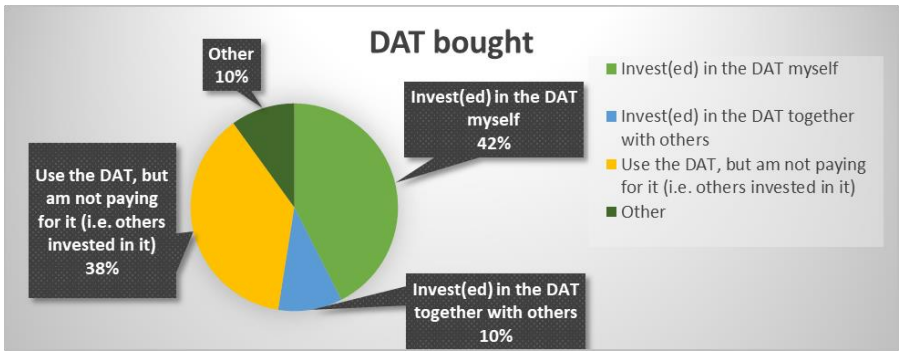


Figure 9: DAT financial investment

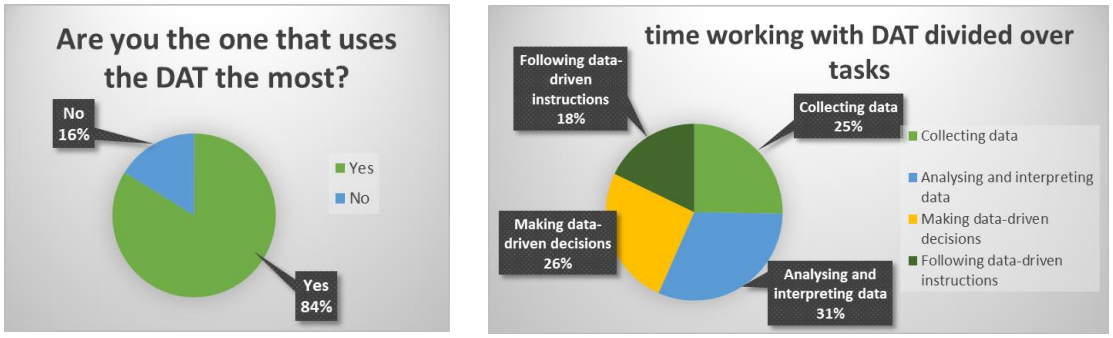


Figure 10: DAT use

Below, factors were prioritised by the respondents on how important they are in their consideration to invest in DATs or not. Because this question is central to determining which aspects are found to be most important overall, the detailed figures are given:

When it comes to making a decision to invest in digital agricultural technology (DAT), we found several factors to be important. Some of these are stated below. Can you place them in level of priority for you, at the time when you made the investment decision for the DAT?			
RANKING*	*ALL*	*bought=1;2*	*bought=3;4*
Factors	**Average placescore**	**self bought/ invested with others**	**not self bought or invested**
Performance of the DAT (e.g. improving yield, reducing costs, ensuring certification)	2,0	1,8	2,2
Ease of use of the DAT (e.g. direct applicability of info, understandable visualisation of data)	2,7	2,5	2,8
Recommendations from my colleagues and/or advisors	4,8	4,6	5,1
Trust in the supplier of the DAT	4,6	4,7	4,4
Trust in how the DAT works (e.g. how my data is secured, and that it is up-to-date)	4,4	4,5	4,1
How the DAT fits with my existing farming practices (e.g. interaction with other technologies)	4,2	4,0	4,4
Cost of the system	3,8	4,8	2,1

**the lower the score the higher the ranking*

Performance of the DAT is rated as the most important, followed by Ease of use. The other reasons come after that.

It is interesting to see if there is a difference between the group that has bought / invested itself in the DAT and the group that has not paid itself. The N is of course a bit thin, but if one looks at “Cost of the system” for instance, a difference can be seen: for the group that has not paid / invested itself in the DAT, the “Cost of the system” has apparently been an important factor, obviously in an inverted way (i.e. because the investment was limited they probably were more inclined to adopt).

When asked if the priorities have changed after using the DAT for a while, most respondents answer that this is not the case, and they also indicate that they are actually working too short with the DAT to be able to determine this properly. However, it is indicated that costs may play a more important role in the future, too.

3.2.1.7. DAT opinions on benefits

For most respondents (78 - 88%), the DAT meets their requirements; is easy to use; they are satisfied with the DAT and believe the DAT helps to sustainably run the farm. 8 - 15% have not decided yet if they are positive or negative about the DAT. Especially whether the DAT is easy to use is not yet possible to answer by everyone. About 5 - 8% is negative about the DAT.

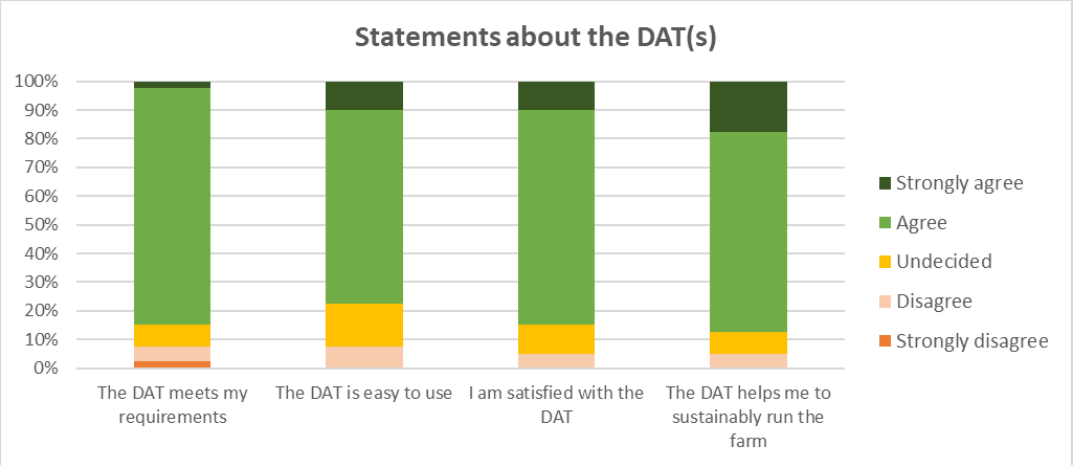


Figure 11: Statements about the DAT

3.2.1.8. Sustainability needs

Respondents were then asked to answer what they would need from a DAT to help with (even) more sustainable farming. Below some of their answers:

"Data to reduce fertilizer, cereals, water, time and other ressources. Or data to send farming in a better perspective for other people"

"To give us a clear instruction on when the fruit should be collected. Issue regional agricultural warnings for [disease] outbreaks and harvest time advice (such as warnings)."

"*Clearer instructions*"

"Easy to use and cheap"

3.2.1.9. DAT impact

Next, they were asked what the biggest change was the farm went through after implementing the DAT. Below follow some of their answers:

"Better performance, critical troubleshooting"

"Irrigation water savings and ease of decision making"

"More quality products"

"More resource efficiency."

"it is always a change to go to a supporting system and that I have to trust on such a system"

"We are able to determine the quality and freshnes of oysters much faster and less destructive. This decreased our costs and improved our speed to the market. Also improved the trust of our buyers. "

The question about the biggest differences between deploying a DAT versus not deploying a DAT resulted in this range of answers:

"Incerased speed in our logistics/productin and incresed trust from consumers with DAT"

"It is true that on the parcel where the telemetry station is installed, there is greater certainty about the validity of the decision taken "

"Above all, being able to control the plots without having to be there in person, when you detect something you move and go to the area in particular, is a great [advantage]"

"Saving in time and a great advance in the speed to make the appropriate decisions"

"Water efficiency. By using the application, I can get more kilograms of product on the side with a certain amount of water than if I do without the application."

These open questions help to understand better the DAT adoption drivers and barriers, in order to prioritise functions and argumentations for further activities in QuantiFarm.

3.2.1.10. Interaction with the DAT

Respondents were then asked to rate their interactions with DAT now, and their ideal interaction, on a slider scale (1 being a basic level of operation i.e. the DAT only monitors; and 8 being the highest level of a fully autonomously operating DAT). This question was added because from dialogues with TC farmers, we saw that the type of relationship a farmer has with the DAT helps to understand adoption dynamics, e.g. perceived risks or fear of autonomy loss.

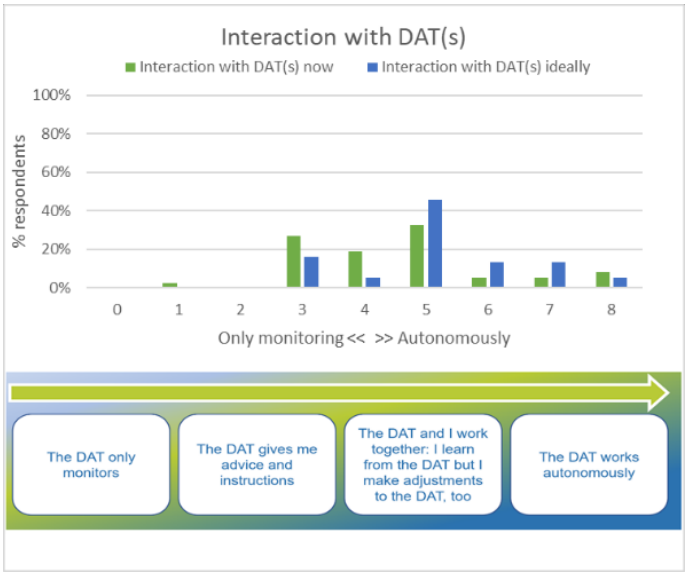


Figure 12: Level of autonomy of the DAT

The graph shows that most farmers place the DAT in the middle of scale (between monitoring versus autonomy, i.e. numbers 3, 4 and 5), and only little on the extremes of 1, 6, 7 and 8. The *ideal* interaction however is higher than these first scores (on 5, 6, 7, and 8), with a clear preference for position 5. This points towards a preference of the farmers that the DAT should ideally become more autonomous, and for instance attain more of a 'co-worker' status, but should not become totally autonomous.

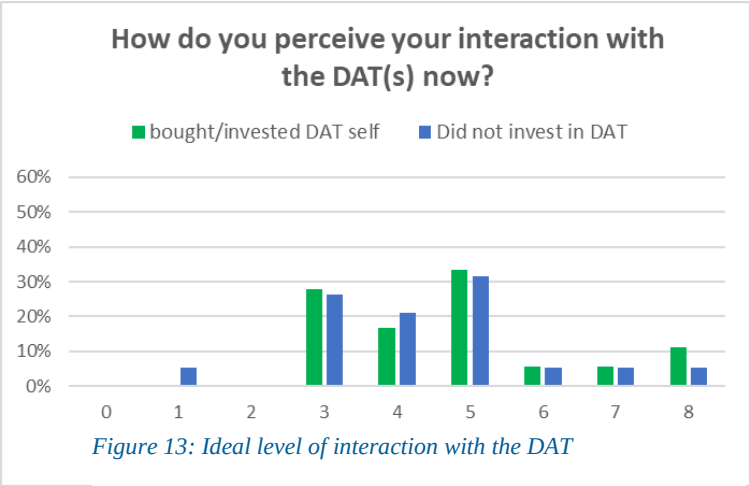


Figure 13: Ideal level of interaction with the DAT

The question on perceived DAT interaction was also compared between farmers who did and did not invest in the DAT themselves. As can be seen in the figure below, the perception is mostly comparable, with main scores in the middle of the scale (3, 4 and 5).

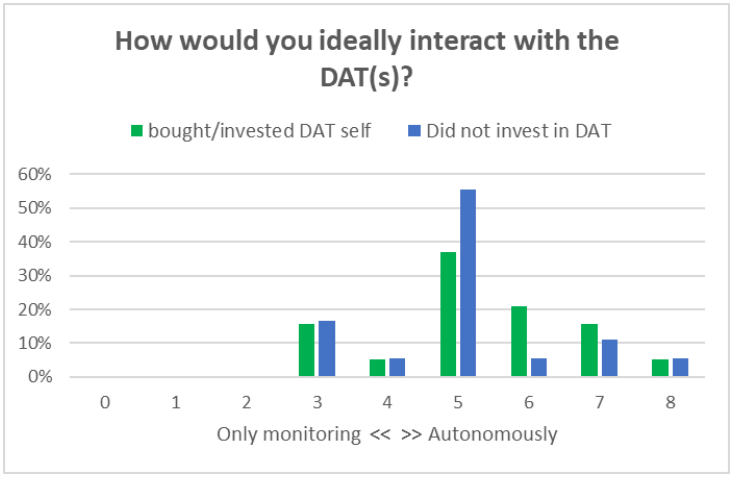


Figure 14: Perceived DAT interaction divided between investment

Below follow some quotes from respondents on the current and ideal DAT autonomy:

"For example in the NDVI. The TAD can tell me that something is happening in that area, but I know my plot and I know that it is a dead sand. I know it's a dead sand, but TAD is not.

"as with evry technology, I belive, that it is best when it is used with some human interaction, to at least check and control its operaitons. Not to be fully autonomous."

"I take into account the advice and instructions provided by the program and in combination with the knowledge and experience I have I do my best for my farms"

Finally, respondents were asked for some other remarks. Comments are quoted below:

"*I think that as the demands are being placed on a farm, Tad [DAT] will become part of the farms as another tool, they will help us in decision-making and they will facilitate them. Communications with the administration, there are many people who do not want to give data, but being able to share data makes us more effective, you can learn a lot from the successes and unwanted results, I never like to say mistakes or failures.*

With Tad [DAT] the data is always stored and accessible. The only problem we have is that we have to improve communications, data coverage so that new technologies work perfectly and do not end up despairing, especially in villages with few inhabitants "

"*The spread of the use of smart farming in the Greek countryside requires coordinated and targeted action by all private and public sector stakeholders who will have to take key decisions and develop strategies that will help in the transition of the new era in the agricultural sector. These actions should be disseminated to the general public and in particular to those directly concerned (agricultural consultants, researchers, producers) with the corresponding means of communication (TV, websites, social media, radio)".*

3.2.2. Survey for DAT non-adopter farmers

All Test Case farmers that are NOT deploying the DAT under assessment by the project, were approached to take part in a survey, regarding their reasons not to adopt the DAT (as described in 2.1.3). Again the survey was web-based, and Test Case managers were asked to send links per Test Case to their respective farmers. On purpose, to make comparisons possible, we kept the survey largely comparable to the previous adopter survey, apart from a few specific questions (which we will see later). The survey was available in 11 different languages (see below). Not all TCs have managed to fully engage actual non-adopter farmers at this point in the project. This became clear in the returned surveys: we had 15 out of 30 TCs responding, with 17 respondents in total (2 TCs had 2 respondents). This number reflects the fact that it is somewhat harder to engage non-adopter farmers at this point in the project.

As for the non-adopter survey, wherever we mention quotes these were translated to English where needed. The answers that already came back in English were left as such (including language mistakes), to prevent interpretation errors and, especially, to reflect the respondent's true words and opinion as much as possible.

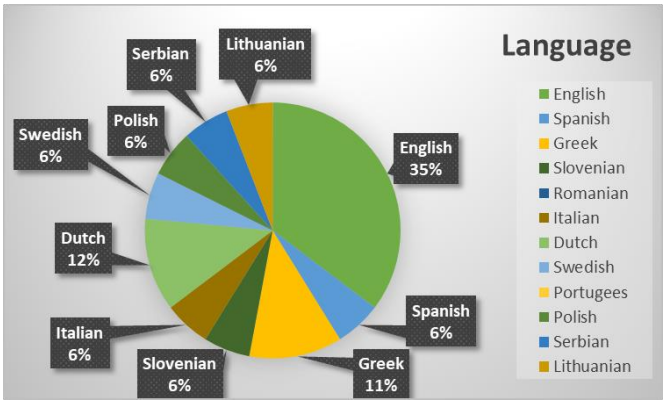


Figure 15: Preferred language

The group of NON-adopters seems to be a bit older than the DAT group in terms of age. 29% is over 45 years old (of the DAT adopters this is 55%); and 41% is over 56 years (of the DAT adopters this is 16%).

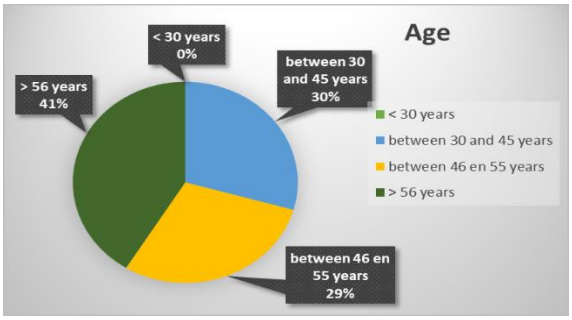


Figure 17: Age category

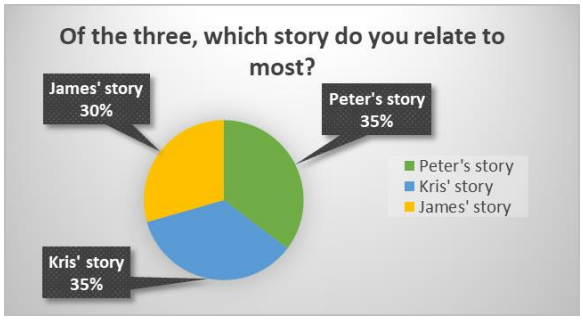
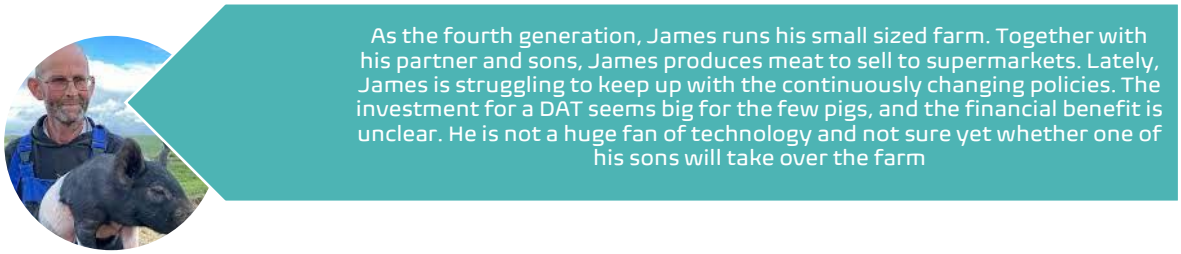


Figure 16: Most relatable farmer story

3.2.2.1. Peter, Kris or James?

To reflect a non-adopter profile in the stories, in this survey we did add a third story, the one of "DAT reluctant" James.



About a third of the non-adopter respondents are attracted to Peter's story, a third to Kris' story, and a third to James' story.

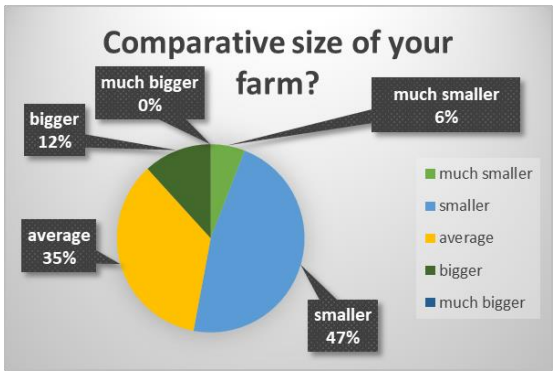
Some reasons farmers choose for James are:

"The technology is very complicated to use, it requires a lot of maintenance."

"The farm is too small to use some expensive technologies"

In comparison, of the DAT adopters, 79% feel most attracted to Peter's story because they share the view that digital resources have an added value for the farm.

3.2.2.2. Farm size and succession



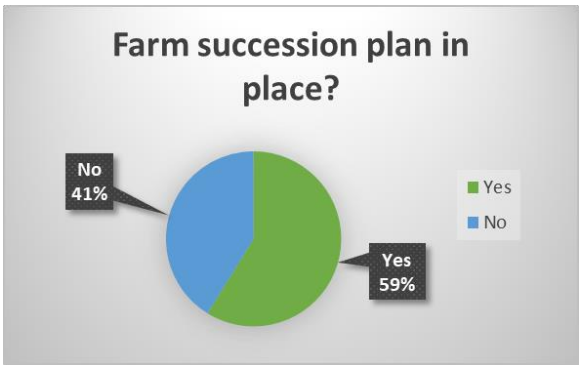


Figure 18: Farm size and succession

The group of non-adopters seem to own relatively small farms (53 smaller farms than comparable farms), also in comparison to the adopter group. Interestingly though, 10% more have a succession plan is place (which is probably related to the older age of the first group).

Also this group of farmers answered the same open questions, with the following answers:

3.2.2.3. Why did you become a farmer?

Mentioned often: family business, family tradition, outdoor living

"We had fields in our possession "

"I had a country and with my family I started doing it spontaneously, about ten years ago"

"I married a farmer and grew to love the business"

3.2.2.4. What are you most proud of as a farmer?

Mentioned often: feeding people, product quality, sustainability

"To manage my farm"

"*For the good quality of my oil* "

"*The sustainability of the farm*"

3.2.2.5. What are your main concerns for your farm?

Mentioned often: regulations, costs

"high costs, low sales prices, fewer and fewer employees"

"buirocracy and climate change "

"High cost and too little financial support, especially to implement technology"

Overall, in their sense of achievement and their concerns, the adopter and non-adopter farmers are rather alike.

3.2.2.6. Affinity with technology

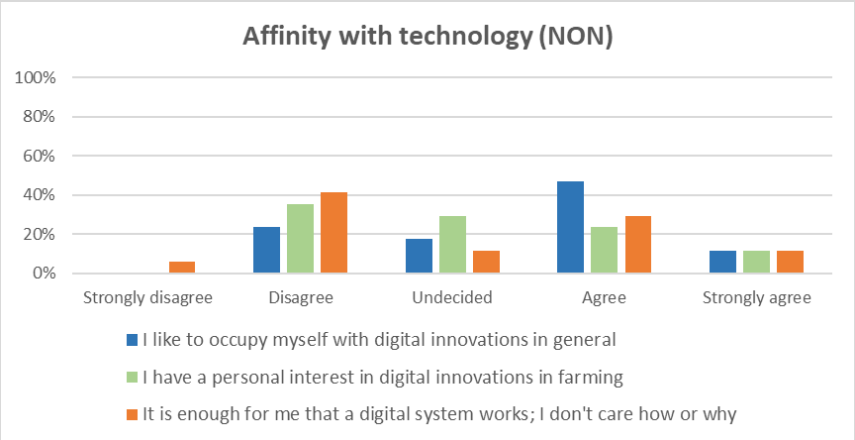


Figure 19: Technology affinity

This group adopters seems less interested in digital innovation compared to the DAT adopter farmers; their interest in digital innovations in general is far lower (59% compared to 93%), and the same for digital innovations in farming (36% vs 83%). This is telling: for the non-adopters the starting point in a potential adoption process will surely not be out of an interest in new technology, gadgets or agritech.

When it comes to making a decision to invest in digital agricultural technology (DAT), we found several factors to be important. Some of these are stated below. Can you place them in level of priority for you, at the time when you made the investment decision for the DAT?	
RANKING*	*Non-adopters*
Factors	**Average placescore**
Performance of the DAT (e.g. improving yield, reducing costs, ensuring certification)	2,6
Ease of use of the DAT (e.g. direct applicability of info, understandable visualisation of data)	3,5
Recommendations from my colleagues and/or advisors	5,6
Trust in the supplier of the DAT	5,3
Trust in how the DAT works (e.g. how my data is secured, and that it is up-to-date)	4,6
How the DAT fits with my existing farming practices (e.g. interaction with other technologies)	3,0
Cost of the system	3,1

**the lower the score the higher the ranking*

"Performance of the DAT" is rated as the most important factor to consider investing in DATs, followed by "How the DAT fits with my existing farming practices", "Costs of the system" and "Ease of use". A significant difference with the adopter farmers: the non-adopters are far more wary about how the DAT fits with their existing practices.

3.2.2.7. Sustainability needs

On sustainability, the following questions were asked:

Could you in your own words describe the tools you use to achieve more sustainability on the farm?

Some representative answers:

"*Basically, we use the experience transmitted from generation to generation, observing the evolution of the plantation and checking the soil moisture. We also rely on weather forecasts*"

"I don't do unnecessary applications"

"*Making observations in the field and anticipating them. Sustainability is not directly linked to digitization.* "

"I don't understand exactly what you mean about the tool. Since I have electricity for pouring in the field, I use electric pumps, and the work in the greenhouse itself is reduced to manual, with the use of various aids, some of which we made ourselves. "

"weather station"

3.2.2.8. What would you need from a DAT to help you (even) more with sustainable farming?

Some representative answers:

"Simple and easy to understand information. for example lack of water, lack of fertilizer, "

"artificial intelligence"

"Sensors to measure carbon fluxs, air quality and slurry/manure/soil analysis. Handheld NIR device for testing forage crops"

And to delve into the motives for non-adoption more we asked:

3.2.2.9. What is the biggest difference you see when deploying a DAT versus not deploying a DAT?

Some representative answers:

"Best example is registering calves online"

"things become managable when we do deploy dat"

"Go with trends or stick with traditional practices"

"In a negative sense, you are only behind a screen and you lose the feeling with the crop, the cultivation and the circumstances "

"Assistance in decision making"

3.2.2.10. Are there tasks on the farm with which you would like to have more digital support? If so, with which tasks?

Some representative answers:

"*Chemical protection support, autonomous tractors"*

"scouting of the sick and plagues and certain extensions in me climate computer"

"Cultivation registration programs and BOS systems are already being used. I think that's more than enough. It can be done in the field anyway."

"No"

"Water purification, and the process of watering and feeding."

"soil condition information"

3.2.2.11. What factors do you find most important for not choosing DAT(s) on the farm?

Some representative answers:

"*Cost. Relevance of the technology when I can do things myself. "*

"ease of use and price"

"The feeling with crop, cultivation and circumstances then goes away. And that's the whole point of being a farmer. "

"*The cost of the investment, and perhaps more importantly not the ability to really first convince myself of the reliability and completeness of the system. "*

What surfaces is a view of farmers who feel a DAT will come in between a farmer and his land / field / crops / animals. Although many farmers are using digital tools to some degree, venturing towards the "smarter" applications feels like being replaced. This view is confirmed by the question on the interaction with the DAT.

3.2.2.12. Interaction with the DAT

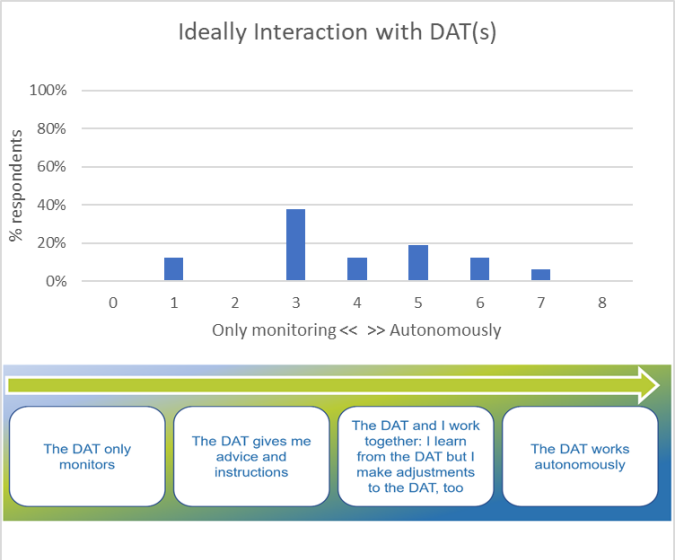


Figure 20: Ideal level of interaction with a potential DAT

Lastly, the respondents were then asked to rate, if they would deploy a DAT, what their ideal level of interaction would be, on a slider scale (1 being a basic level of operation i.e. the DAT only monitors; and 8 being the highest level of a fully autonomously operating DAT). This question was comparable to the "ideal interaction" question in the adopter survey. Not surprising, the non-adopters would appreciate some degree of advice, but not much more. Some open answers:

"some decisions can be fatal to our production so final decisions must be made by a human "

"If it's only as a monitor, there are already so many uses of that and really should offer something extra that isn't there yet. "

"The point is to give reliable technology parameters to maintain and upgrade along the way."

Although we offered them the possibility, we received no other open feedback as we did from the adopter farmers.

3.3. Outcomes in-depth study on non-adoption (SFYN)

The earlier-mentioned organisation SFYN (chapter 2.1.4), in collaboration with TNO, investigated motivations of farmers who are not adopting DATs. Through a field visit, followed by a semi-structured interview and a futuring exercise, eight farmers shared their stories. The method itself, including the description of futuring, is part of Appendix C.

The visits provided insights in the determinants for not working with any type of (digital) technology. We hypothesised that non-adoption could either be because farmers can not (e.g. due to financial reasons) or do not want to adopt technology (e.g. due to ethical reasons).

The target audience for the research was scoped using the following matrix:

Sector / Type	Arable	Livestock	Horticulture	Fruit farming
Common	Farmer A	Farmer B	Farmer C	Farmer D
Organic	Farmer E	Farmer F	Farmer G	Farmer H

Outcomes of the research has led to an estimation of the degree of adoption; reflections on three archetypes; and lastly an overview of the interviews, summarised in a presentation[4].

3.3.1. Degree of adoption

Based on the interviews (and very much aligned with the survey outcomes of the paragraphs above), it was found that one can discern a degree of DAT adoption, from the basic monitoring solutions to the fully autonomous ones. In this part of the research, an adoption degree per sector was distinguished, based on dialogues with the farmers in the research:

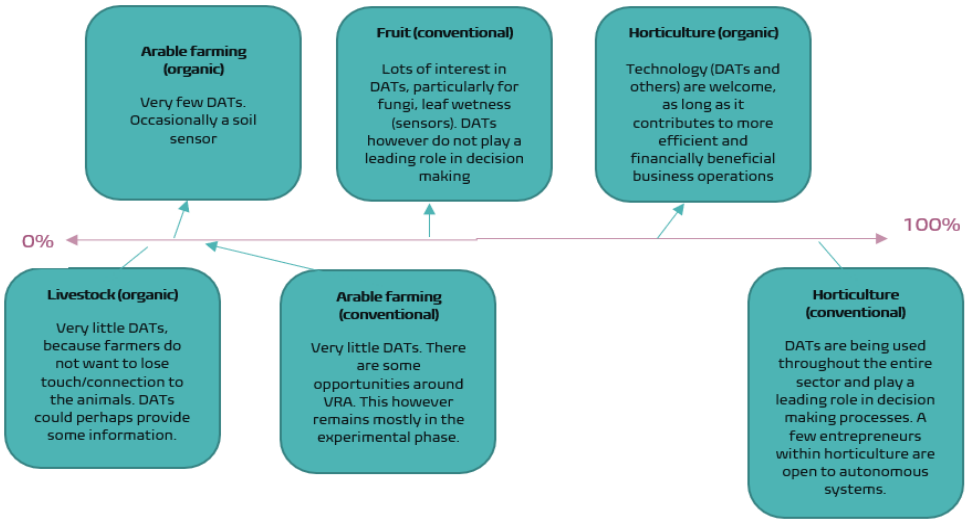


Figure 21 Adoption degrees per sector

The interviews with both farmers and experts in the field of agriculture during the half a year program led into several insights:

- DAT adoption is a gradual process, not a binary matter of either 'yes' or a 'no';
- Not only the presence of a DAT was taken into account, but also its role in farmer decision-making process defines the adoption degree;
- There seems to be a correlation between the adoption degree and the input intensity of a sector, as farmers who stated to by highly reliant on inputs for their production are in practice more prone to look into supporting DATs to decrease this reliance;
- And there seems to be less DAT adoption in organic farms in comparison to non-organic (conventional) farms. Probably because organic farmers are less tempted to focus on profit.

3.3.2. Archetypes

Based on the interviews, three archetypes (generalised representations of farmers, with certain contexts and traits) were abstracted from the data. This was done by clustering and connecting recurring

[4] Please contact sabine.verdult@tno.nl to get access to this file.

behavioural determinants in the data, through which three distinct types surfaced. The archetypes, and their characteristics, are described below. Interestingly, we see parallels with the data from our non-adopter survey and the literature review, such as the older (more experienced) farmer with a smaller-sized farm being the most reluctant, and the ones open to some form of DATs, but without a compromise on their autonomy and (image of) being an ecologically-driven farmer.

Figure 22 Non-adopter archetypes

4. The integrated DAT adoption framework

As we have seen, to truly understand DAT adoption, it is essential to capture farmers' experience of DAT adoption throughout the process of decision-making, from first thought of potential procurement, up and until full usage of the technology.
The literature research, combined with the Test Case visits, survey and SFYN study, produced such a breadth of knowledge around DAT adoption and revealed such a range of influences, that it seemed the most comprehensible way to unite all of them is via a new integrated framework. The novelty of this particular QuantiFarm framework stems from its incorporation of different perspectives on determinants, and simultaneously framing of DAT adoption as a journey (rather than a singular moment), which begins with an initial encounter and consideration, and ends with habitual use and total integration of the DAT.

The framework came about by clustering and structuring the above-described findings in a few iterations, after which a visual artist supported the concept with an illustration.

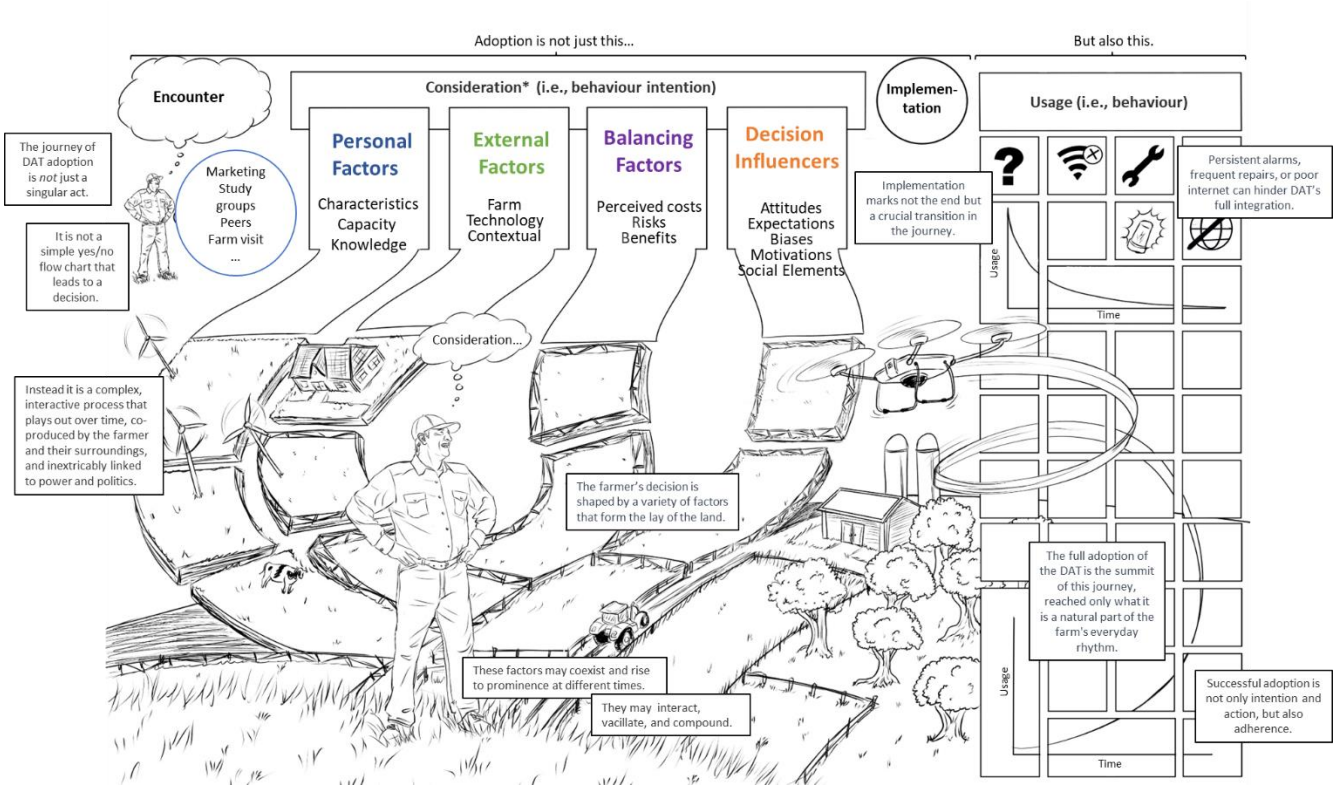


Figure 23 QuantiFarm integrated DAT adoption framework - overview

The framework tells the story of how the adoption journey starts with an encounter with (a) DAT, either by chance, marketing campaigns, mentioning by peers, other research programs, etc. This is followed by an elongated phase of consideration, in which many determinants are at play that can be clustered into 4 groups, which all come together in the decision sphere of the farmer and his or her farm:

- Personal factors, which are those factors personal to the farmer such as age, gender, education level, skills, and time to spend on learning new things;
- External factors, which are not individual determinants as such but do influence the farmer's choices and behaviour, such as scale of the farm, farming type, local traditions and complexity of the DAT;

- Balancing factors, which are the factors that make a farmer weigh his or her decisions, such as perceived risks of implementing (or not implementing) a DAT, expected maintenance costs, and expected returns;
- Decision influencers, that can be regarded as a subjective layer around the balancing factors and which are not always necessarily based on rational weighing of costs and benefits. In this category we fit determinants such as attitude towards the risks in the previous category; how one perceives he or she is actually capable of working with technology, life goals, and, prominently, social influences of the people around the farmer.

After going through this process of consideration, often going back and forth between factors, follows an implementation decision, which may be the decision not to implement anything (now); a trial, or full-blown roll-out, and variations in between, such as trialling one part of the DAT solution, followed by another, etc. Lastly, though highly significant, is the usage phase, in which still many factors influence how well a DAT is actually adopted and whether it can perform optimally. This is where expectations, e.g. on performance, ease of use, or interactions with other technologies, are met (or not) in practice. The open boxes in the illustration depict indicators that can be filled in over the course of the project, by the assessments conducted in WP2 and repeat studies of findings on actual DAT usage in WP1. Lastly, dealbreakers to be aware of, that can also cause for a DAT to be no longer deployed, are items such as the DAT leading to an overload of work, or intrusiveness of alerts.

All the specific determinants are added to the framework below:

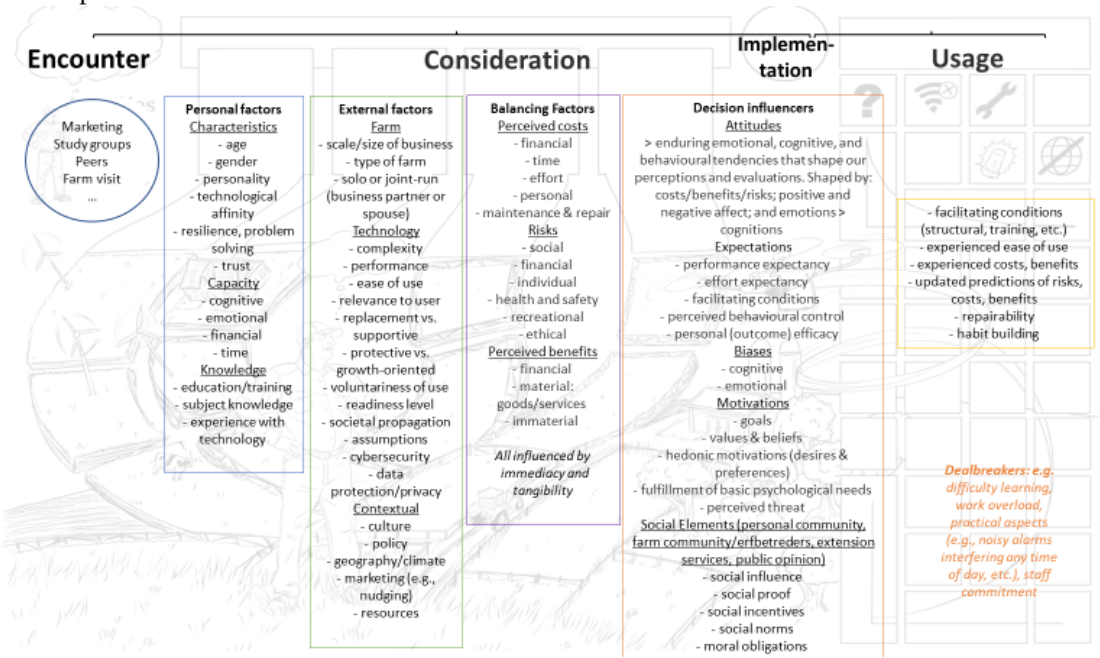


Figure 24 QuantiFarm integrated DAT adoption framework – with determinants

The framework is intended to be applied in several ways. Firstly, it serves as a comprehensive overview of determinants to be used as a reference making sure consequent guidelines are relevant and complete. Secondly, it is a means to incorporate the right indicators in the tools and instruments that are being developed by other Work Packages of the project. Thirdly, it supports the dialogue with stakeholders on what are elements to consider in light of DAT uptake and usage. Please note that this is a first version of the framework. The path ahead for the QuantiFarm project is to see which elements surface as most prominent over the coming years, which ones are of less importance, or which ones were overlooked.

5. Farmer stories

Data is telling, but often lacks vividness and the capacity to truly empathise with the respondents behind the data. However, to take next steps such as defining guidelines to support with DAT uptake, this empathy is crucial. Therefore, to illustrate how an individual farmer's decision-making process may unfold, driven by this myriad of factors, a series of short farmer stories are outlined. Different factors are relevant to different individuals, and these factors change over time and situation to situation. To demonstrate this, each story introduces a farmer character and highlights the circumstances and influences that lead them to adopt a DAT (or not). The stories exemplify what a hypothetical farmer's "DAT adoption journey" could look like. A second step is to turn the stories into actual visual stories, or storyboards, to make it even more vivid. For our first story below, such a story has been created which is added below. These storyboards will form the basis of interactions with stakeholders on the implications of the behavioural findings so far in this project.

The farmer profiles in the stories were informed by all research outcomes described in chapter, and the consequent framework in chapter 4, in order to be realistic and representative. Please note that over the course of the project, the farmer stories will develop: our Test Case farmers are moving along the adoption process themselves, which will certainly lead to updates in our insights.

The colour codes match the colour codes of the determinants in the DAT adoption framework:

- Personal factors;
- External factors;
- Balancing factors;
- Decision influencers;
- Usage phase

5.1. Farmer 1: securing the legacy through digitalisation

We see a 35-year-old male, father of 2 children. He recently began the take-over of the family legacy farm from his father. The son has a fairly strong affinity with technology (i.e. he is interested in using technology and understanding how it works); in fact, he is very committed to the family legacy, and sees technology as a means to achieve this as both may well be intertwined. He experiences a lot of pressure though: weighed down by the constantly changing regulations, and worried about drought that bears down on the land, he has to invest in the future despite of these insecurities. Moreover, he feels the negative public opinion of farmers being big consumers ('wasting') of water also is aimed towards him. Not from the people he knows in the village perse, but from the trends he picks up in the media.

Father is a sceptic of DATs; he grumbles that instead he can smell when crops need to be watered. Nevertheless, given their shared love for the farm and that sustainability is essential for its future, he agrees to a trial. The son decides to test a precision irrigation system with decision-support that he knows farmers in the region and their advisors are using and that he has seen on a recent farm visit, so they can help him to smoothen the implementation process. He gets right into figuring out how to make the most of the new system, and quite easily manages to consult the dashboard in his daily routines. He prefers to be able to make some necessary adjustments himself, and with the help of others, he can to some extent.

A while later, his work-life balance turns out different than it used to be for his father. The son sees the DAT as an extra set of eyes; he can now even check on the farm from the comfort of his home. He is still continuously concerned with this farm, but he feels confident because of the support from the system to make far more targeted decisions to irrigate the crops. He decides to invest in the system longer term. Deep in his heart he hopes he leaves the farm in such a way that his son or daughter can

also live a good life being a farmer. He ponders over how they will learn how to farm, as DATs will take over parts that were once intuitive, and how the data he is now collecting may serve as the knowledge base for the children that replaces this while maintaining the love for farming.

The storyboard for this story can be found in appendix D.

5.2. Farmer 2: digital autonomy

We see a farmer in his fifties. He owns a large potato farm in north-west Europe together with his wife. He is supported by seasonal staff and his trusted advisor that he has known over the years. Seasoned by many years of expertise, he became a familiar face in government/EU-led research programs on digitalisation in farming, whilst managing his own farm. He has affinity with innovation and research, and is thus willing to pilot new things. Besides, by offering his services as a pilot farmer he can generate an extra income stream. Currently, he was asked by his advisor to join a pilot program on a variable rate application camera and sensors, that results in advice on the targeted application of inputs for the crop. It is installed an supported by a DAT provider.

Specifically dealing with data-driven decision-making support, he has seen a few of them come by over the years. In fact, this experience has increased his reluctance to fully invest in a solution by himself. He has not seen one yet that could reliably replace his knowledge, which makes that he feels he should always double-check. Even though he indeed sees that his solution lead to some input reduction, overall he is wary of being locked in if he chooses to fully invest in this DAT: what will happen to the data that his farm his collecting, what happens to the decision support if for some reason it does not work, and in how far will it make him dependent on the specific DAT supplier that works on the basis of his own data? His own advisor is not fully capable of supporting him on these questions. He, and his wife who has just as much a say in the farm investments, will need clarity on these matters for him to decide to invest in such a solution himself.

5.3. Farmer 3: ardent and prudent pig farmer

We see a 55 year old female pig farmer. Her farm is relatively big and although it was run by her husband's family for generations, she is now solely managing the pigs as the rest of family is earning an income in other ways, such as the camp site at the other end of the village. This is a necessity, as the margins for pig meat are increasingly low. Apprehensive of how the market prices will develop, she is looking for ways to decrease her costs, especially the use of antibiotics.

She is an avid visitor of fairs and conferences and extremely knowledgeable about her field. At one such fair she encountered a DAT that can help bring antibiotics use down: a pig welfare monitoring system. Besides the fact that she is willing to venture into new things to have happier and healthy pigs, she does estimate this DAT will reduce her costs and maybe even improve her market position with cleaner pig meat. Moreover, the pressures from government to regulate the pig farms from an ecological standpoint makes her seek for ways to run her business more sustainably. This in spite of the fact that her trust in government is low: it seems they mend market failures with complicated subsidies, and also, living near the border, it sometimes feels life is far easier just a few kilometres down the road, where the other country's regulations are less stringent.

Investing in the DAT right off the bat is not a straightforward matter though: although not afraid to try new things, she is prudent regarding her investments and she is more afraid of incurring losses in these risky times than generating extra income or even grow her farm. Given the pressures she feels, and the fact that she has to do a lot by herself, her emotional ability to cope with big changes is low. Thus, as fast as she can makes decisions regarding her pigs well-being; all the more time she takes to consider the options regarding investing in a new DAT.

5.4. Farmer 4: business mentality

We see a young entrepreneur, 34 years old, who together with a business partner just bought a middle-size farm with grapevines, with a winery on location where he started to bottle his own wines and host tastings. He loves being outside, reaping the fruits of his labour and enjoying his wines, yet at the same time he is a business man; just the way he was educated as an agronomer at the local university. Despite occasional civil instability in his country, he, as many younger farmers in his region, has a strong love for the local heritage. This results in a desire to preserve the country's nature and local culture. Even more so than the older farmers it sometimes seems, as they often not open to innovate.

He is currently weighing his options of investing in more DATs (besides the drone he occasional employs to map the field), especially sensors and a DSS for soil and plant measurements so he can grow a variety of local, indigenous grapes. As he is more driven by benefit maximalisation rather than risk reduction, and is fairly comfortable dealing with digital technologies, he turns most focus to the performance he expects from the DAT and the potential financial gains (rather than how easy it is to use, for instance). The price tag is relatively high, but he had the finances ready for this venture, so he has the funds to invest.

He has the time to do some research on the DAT, for instance by asking peers, because he has dedicated this period of time to getting his new business off the ground. He does have a slight unease towards his business partner though, who prefers to keep things more traditional. So, what if the DAT performance stays behind? And towards his peers: what if a lesser performance seems it is because of his own incompetence to work well with it?

With his rational mentality, he gets over these doubts and directly contacts a well-known DAT supplier. They team up on the roll-out of a soil management system first. Luckily, the farm is not yet entrenched with old habits, so he can develop new ones. He envisions a farm where more and more is even done autonomously in the future.

5.5. Farmer 5: non-adopter in doubt

This 43-year old farmer has a middle-sized, family owned farm. Together with her partner and sometimes their two sons, she produces some meat to sell to supermarkets and sells other products locally in her farm shop. Next to this, the farm works together with a school nearby so children can come by and learn how a farm works and food is produced. The farm is a much loved place in the local community. Everyone is welcome on the farm, it operates very transparently and people from around the area loyally visit the shop.

The farm does not operate organically - although already it uses just a few chemicals- but the farmer wants to become certified as organic. This feels to her as a moral obligation, and aligns with the community values: providing them with healthy products, and leaving them a healthy earth.

The increasing number of rules she needs to adhere to for delivering meat to the supermarket chain, feel very demanding. Therefore, she is contemplating to adopt a supporting digital technology. An advisor that she knows via another farmer, mentioned their new measurement instrument that can provide the metrics she needs for certification. Also, the system helps feeding the livestock in exact amounts, fitting with their needs in their stage of growth.

The DAT seems it could help her save time, so she can dedicate more time to the other tasks around the farm and her work in the community. However, her list of negative factors that she weighs is long. For instance, the investment for the low amount of pigs seems relatively big, and the potential for scaling is limited. And whether a son will follow in her footsteps on the farm is still too soon to tell, so the time span for a return on her investment is limited, too. This makes it difficult to do an analysis of what it

will save her, financially and time wise. Furthermore, she questions the longer-term impact such a DAT may have. She now knows exactly what the animals need, and is afraid to lose that knowledge and insights on the wellbeing of the pigs if a tool replaces this. Lastly, the technology would perhaps change the image of the farm towards its community. She decides to do a trial for six months to at least experience how the tool works, before she is going to weigh her options further.

6. Conclusion and further steps

In the first year of the QuantiFarm project, thanks to the diligent cooperation of many project partners, WP1 has been able to already collect a significant amount of data. This way we have managed to gain a baseline understanding of the behavioural dynamics at play around the phenomenon of DAT adoption, which can be used as a reference work for coming research and activities.

It is self-evident to posit that DAT adoption is a complex domain consisting of a myriad of determinants, surfacing at different times, in different magnitudes. And add to this the differing between farmers and farming contexts. By means of the integrated framework on DAT adoption and the farmer stories an attempt is made to create a comprehensive overview of this complex domain. However, from this body work, we also see a picture emerging that does unite all the findings. This is a picture of a sector under significant pressure: amongst others, because of the effects of climate change; more stringent regulations; insecurity about future prospects, and changing consumer demands. The origin of the QuantiFarm project is the awareness that DATs are a means to support farmers with these pressures. What the findings in QuantiFarm so far uncover however is that there is a group tiptoeing into (more) DAT adoption, and that can be supported into venturing into this domain more with the right levels of transparency, information, and tools that really meet their individual needs.

There is still an exciting journey ahead for WP1 in the coming years. Firstly, this baseline analysis of behavioural dynamics is translated, together with project partners and a wider group of stakeholders, into actionable guidelines that help farmers in their decision-making process, uptake and usage and of DATs. Secondly, progress on the findings will be tracked, for instance by repeating the surveys and conducting more Test Case farm visits. In parallel, WP1 will dive further into separate research streams that have surfaced during this first year and deserve more attention. For instance, how do we account for gender differences, and cultural differences in the findings? What role do advisors play (and what role should they play)? And how does the type of DAT influence the adoption process? And for sure, many more questions to come.

7. References

- Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In Kuhl J.and Beckmann J.(eds.). Action Control: From Cognition to Behavior. New York: Springer-Verlag. 3, 11-39.
- Anderson, B. (2010). Preemption, precaution, preparedness: Anticipatory action and future geographies. Progress in human geography, 34(6), 777-798.
- Attig, C., Wessel, D., & Franke, T. (2017). Assessing personality differences in human–technology interaction: An overview of key self-report scales to predict successful interaction. In C. Stephanidis (Ed.), HCI International 2017 – posters' extended abstracts, part I, CCIS 713 (pp. 19–29). Cham, Switzerland: Springer International Publishing AG.
- Barnesa, A.P., Sotob, I. , Eorya, V., Beckc, B., Balafoutise, A.T., Sanchez, B., Vangeyte, J., Fountas, S., Van der Walg, T., Gómez-Barberob, M. (2019). Influencing incentives for precision agricultural technologies within European arable farming systems. Environmental Science and Policy 93 (2019) 66–74
- Boerenverstand (2021). S2-E03. HP Prangsma: De Boer die wil blijven boeren [podcast].
- Davis, F.D. (1986). Technology Acceptance Model for Empirically Testing New End-User Information Systems: Theory and Results. Cambridge: MA. MIT Sloan School of Management.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information Technology. MIS Quarterly, 13(3): 319–340.
- Davis, F.D., Bagozzi, R.P., Warshaw, P.R. (1992). Extrinsic and intrinsic motivation to use computers in the workplace. Journal of Applied Social Psychology, 22, 1111–1132.
- Davis, F.D., Bagozzi, R.P., Warshaw, P.R. (1989). User Acceptance of Computer Technology: A Comparison of two Theoretical models. Management Science. 35(8), 982-1003.
- Fishbein, M. Ajzen, I. (1975). Belief, attitude, intention and behavior: An introduction to theory and research. MA: Addison-Wesley, 1975.
- Franke, T., Attig, C., & Wessel, D. (2019). A Personal Resource for Technology Interaction: Development and Validation of the Affinity for Technology Interaction (ATI) Scale. International Journal of Human–Computer Interaction, 35(6), 456-467.
- Hekkert, P., & van Dijk, M. (2011). Vision in design: A guidebook for innovators. BIS.
- Huang, K-Y., Choi, N., & Chengalur-Smith, I. (2010). Cultural dimensions as moderators of the UTAUT model: a research proposal in a healthcare context. AMCIS 2010 Proceedings, 188.
- Psychological influences on biosecurity control and farmer decision-making. A review
- Mankad, A., (2016) Psychological influences on biosecurity control and farmer decision-making. A review. Agron. Sustain. Dev., 36 (2016), p. 40
- Meierová, T & Chvátolavá, V. (2022). Frustrated or fulfilled? Motivation of Czech farmers to implement climate change adaptation measures on the landscape level. Journal of Rural Studies. Oxford: Elsevier, 2022, vol. 92, May, p. 354-370.
- Miller†, N. Griffin, T., Bergtold, J.,Ciampitti, I., and Sharda, A. (2017). Farmers' Adoption Path of Precision Agriculture Technology. Advances in Animal Biosciences: Precision Agriculture (ECPA) 2017, (2017), 8:2, pp 708–712
- Marra, M., Ghadim, A., Pannell, D. (2003). The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve? February Agricultural Systems 75(2-3):215-234
- Moysiadis, V., Sarigiannidis, P., Vitsas, V., Khelifi, A. (2021). Smart Farming in Europe. Computer Science Review 39, 100345
- Naspetti, S., Mandolesi, S., Buysse, J., Latvala, T., Nicholas, P., Padel, S., Van Loo, E. J., & Zanoli, R. (2021). Consumer perception of sustainable practices in dairy production. Agricultural and Food Economics, 9(1)

- Paustian, M. and Theuvsen, L. (2017) Adoption of precision agriculture technologies by German crop farmers. Precision Agriculture volume 18, pages 701–716 (2017)
- Rogers, E.M. (2003). Diffusion of innovations, 5th ed., New York: Free Press, p. 512.
- Rose, D.C., Parker, C., Fodey, J., Park, C., Sutherland, W.J., Dicks, L.V. (2017. Involving stakeholders in agricultural decision support systems: Improving user-centred design. International Journal of Agricultural Management, 6(3/4) 80 & 2017
- Schimmelpfennig, D., & Ebel, R. (2016) Sequential Adoption and Cost Savings from Precision Agriculture. Journal of Agricultural and Resource Economics, Volume 41, Number 1
- Sirris, S., Lindheim, T., Askeland, H. (2022). Observation and Shadowing: Two Methods to Research Values and Values Work in Organisations and Leadership. In: Espedal, G., Jelstad Løvaas, B., Sirris, S., Wæraas, A. (eds) Researching Values. Palgrave Macmillan, Cham
- Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories. Procedia Manufacturing 22, 960–967.
- Van der Walg, T., Gómez-Barberob, M. (2019). Influencing incentives for precision agricultural technologies within European arable farming systems. Environmental Science and Policy 93, 66–74
- Van Velthoven, B.C.J. (2012). Economie van misdaad en straf. Den Haag: Boom Lemma.
- Venkatesh, M., & Davis, F.D. (2003). User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly, 27 (3), 425.
- The farming podcast (2018). Episode-130 How to make a small farm profitable [podcast].
- Thompson, R.L., Higgins, C.A., and Howell, J.M. (1991). Personal computing: Toward a conceptual model of utilization. MIS Quarterly. 15(1) (1991) 124-143.
- Work Package 1 report: QuantiFarm_ Report on Test Case farm visits M1-M12
- Work Package 4 deliverable: QuantiFarm D4.1 Testing and Assessment Guidelines

8. Appendices

Appendix A – Survey DAT adopter farmers

Survey about the adoption of digital agricultural technologies (DATs)

This survey is meant to be filled out by the farmer, or employee on the farm, that is both familiar with the DAT and has a say in the decision-making to deploy DAT(s) on the farm.

INFORMED CONSENT

I declare to participate voluntarily in the study, entitled QuantiFarm. I confirm that the intentions of the research and the approach followed have been explained to my satisfaction. I have had the opportunity to ask additional questions and these questions have been answered satisfactorily. I have had sufficient time to think about participation.

I know that my participation in the study is completely voluntary and that I can withdraw my consent at any time without providing a reason. I give permission to process my personal data for the purposes described in the information.

I give explicit permission for the processing of special personal data: ideological and generic economic data. I give permission to reuse my research data for future research in the research area described, provided that it is coded in such a way that it can no longer be traced back to me as a person.

I give permission for the data to be stored and for authorized members of the research team and authorized inspectors to have access to it.

Furthermore, I declare that I have no known impediments to participate in the research.

□ Yes, I declare

Below you can read two stories of fictional test case farmers in QuantiFarm, inspired by real stories. Please read them first.

Of the two, which story do you relate to most?

- ☐ Peter's story
- ☐ Kris' story

Why?.....

If you compare the size of your farm to other farms in the same sector in your region, how would you estimate the comparative size of your farm?

- ☐ Much smaller
- ☐ Smaller
- ☐ Average
- ☐ Bigger
- ☐ Much bigger

Why did you become a farmer?.....

What are you most proud of as a farmer?.....

What are your main concerns for your farm?.....

What is your age?

- ☐ < 30 years
- ☐ Between 30 and 45 years
- ☐ Between 46 and 55 years
- ☐ 56 years
- ☐ I'd rather not say

Do you have a farm succession plan in place?

- ☐ Yes
- ☐ No

About your affinity with technology, could you answer the following statements?

	Strongly disagree	Disagree	Undecided	Agree	Strongly Agree
I like to occupy myself with digital innovations in general					
It is enough for me that a digital system works; I don't care how or why					
I have a personal interest in digital innovations in farming					

Could you in your own words describe the DAT that is the central DAT for your test case in QuantiFarm? NB: the remainder of this survey will deal with this DAT.

Please choose: I..

- ☐ Invest(ed) in the DAT myself
- ☐ Invest(ed) in the DAT together with others
- ☐ Use the DAT, but am not paying for it (i.e. others invested in it)
- ☐ Other:…….

Are you the one that uses the DAT the most?

- ☐ Yes
- ☐ No, it is mostly used by:.....

Several data-related tasks can be linked to working with the DAT. Can you please assign to what task, in percentages, you devote the most time when working with the DAT?
You can divide 100% over the tasks below.

Task	%
Collecting data	
Analysing and interpreting data	
Making data-driven decisions	
Following data-driven decisions	
Other:	

When it comes to making a decision to invest in digital agricultural technology (DAT), we found several factors to be important. Some of these are stated below. Can you place them in level of priority for you, at the time when you made the investment decision for the DAT?

You have to drag each item to the space above.

Performance of the DAT (e.g. improving yield, reducing costs, ensuring certification)
Ease of use of the DAT (e.g. direct applicability of info, understandable visualisation of data
Recommendations from my colleagues an/or advisors
Trust in the supplier of the DAT
Trust in how the DAT works (e.g. how my data is secured, and that it is up-to-date)
How the DAT fits with my existing farming practices (e.g. interaction with other technologies)
Cost of the system

When using the DAT for a longer time these priorities may change. Did they in your case? And if so, how and after how long did they occur?.....

Please indicate to what extent you agree or disagree with these statements.

	Strongly disagree	Disagree	Undecided	Agree	Strongly Agree
The DAT meets my requirements					
The DAT is easy to use					
I am satisfied with the DAT					
The DAT helps me to sustainably run the farm (economic, environmental and/or social)					

What would you need from a DAT to help you (even) more with sustainable farming?.....

What was the biggest change your farm went through before and after implementing the DAT?.....

What is the biggest difference you see when deploying a DAT versus not deploying a DAT (e.g. on a different plot)?.....

How do you perceive your interaction with the DAT now? You can indicate the most fitting place on the scale with the slider

Click on the black slider bar to place the control handle.

Only monitoring Autonomously

How would you ideally interact with the DAT? You can indicate the most fitting place on the scale with the slider

Only monitoring Autonomously

Could you elaborate?.....

[END]

Appendix B – Survey DAT non-adopter farmers

This survey is meant to be filled out by the farmer, or employee on the farm, that is both familiar with the DAT and has a say in the decision-making to deploy DAT(s) on the farm.

INFORMED CONSENT

I declare to participate voluntarily in the study, entitled QuantiFarm. I confirm that the intentions of the research and the approach followed have been explained to my satisfaction. I have had the opportunity to ask additional questions and these questions have been answered satisfactorily. I have had sufficient time to think about participation.

I know that my participation in the study is completely voluntary and that I can withdraw my consent at any time without providing a reason. I give permission to process my personal data for the purposes described in the information.

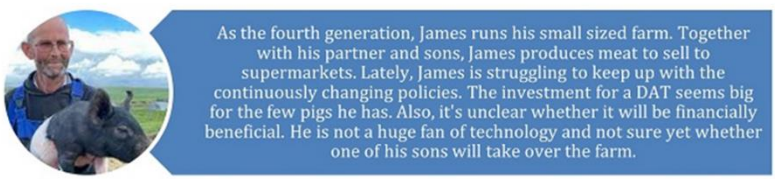
I give explicit permission for the processing of special personal data: ideological and generic economic data. I give permission to reuse my research data for future research in the research area described, provided that it is coded in such a way that it can no longer be traced back to me as a person.

I give permission for the data to be stored and for authorized members of the research team and authorized inspectors to have access to it.

Furthermore, I declare that I have no known impediments to participate in the research.

□ Yes, I declare

Below you can read three stories of fictional test case farmers in QuantiFarm, inspired by real stories. Please read them first.



Of the three, which story do you relate to most?

- ☐ Peter's story
- ☐ Kris' story
- ☐ James' story

Why?.....

If you compare the size of your farm to other farms in the same sector in your region, how would you estimate the comparative size of your farm?

- ☐ Much smaller
- ☐ Smaller
- ☐ Average
- ☐ Bigger
- ☐ Much bigger

Why did you become a farmer?.....

What are you most proud of as a farmer?.....

What are your main concerns for your farm?.....

What is your age?

- ☐ < 30 years
- ☐ Between 30 and 45 years
- ☐ Between 46 and 55 years
- ☐ 56 years
- ☐ I'd rather not say

Do you have a farm succession plan in place?

- ☐ Yes
- ☐ No

About your affinity with technology, could you answer the following statements?

	Strongly disagree	Disagree	Undecided	Agree	Strongly Agree
I like to occupy myself with digital innovations in general					
It is enough for me that a digital system works; I don't care how or why					
I have a personal interest in digital innovations in farming					

Could you in your own words describe the tools you use to achieve more sustainability on the farm?

Are you the one that uses the tool(s) the most?

- ☐ Yes
- ☐ No, it is mostly used by:.....

Are there tasks on the farm with wich you would like to have more digital support? If so, with which tasks?.....

When it comes to making a decision to potentially invest in digital agricultural technology (DAT), we found several factors to be important. Some of these are stated below. Can you place them in level of priority for you?

You have to drag each item to the space above.

Performance of the DAT (e.g. improving yield, reducing costs, ensuring certification)
Ease of use of the DAT (e.g. direct applicability of info, understandable visualisation of data
Recommendations from my colleagues an/or advisors
Trust in the supplier of the DAT
Trust in how the DAT works (e.g. how my data is secured, and that it is up-to-date)
How the DAT fits with my existing farming practices (e.g. interaction with other technologies)
Cost of the system

What factors do you find most important for not choosing for DAT(s) on the farm?.....

What would you need from a DAT to help you (even) more with sustainable farming?.....

What is the biggest difference you see when deploying a DAT versus not deploying a DAT?...

In a situation where you would potentially deploy a DAT, how would you ideally interact with the DAT? You can indicate the most fitting place on the scale with the slider

Only monitoring Autonomously

Could you elaborate?.....

[END]

Appendix C – SFYN research approach

Workshop

Visits to farmers, restaurants, entrepreneurs, scientists and politicians are organised during the academy. Furthermore, the group is divided into five subgroups, working on a case study, in order to put their knowledge into practice. During the half a year, the research question, method and presentation of the results are supported by workshops and masterclasses by professional researchers, (pitch) trainers and/or designers.

Figure 25 SFYN x TNO workshop 18.02.2023 Rotterdam

Based on QuantiFarm's TCs, SFYN aligned their target audience with the same type of farmers. E.g. wherein QuantiFarm's program were TCs of livestock farmers with technology (adopter), SFYN made sure a livestock farmer without technology (non-adopter) was represented[5].

At the beginning of their field visits, SFYN formulated their mission within the assignment as follows:

> *"In a world in which efficiency is the new standard, data is the new gold and digital technology becomes more accessible, we want to understand farmers' resistance or inability to adhere to this new standard. This so they will also have a voice in the future of agriculture" _*
>
> SFYN x TNO Group, A. Brouns; J. de Koeijer: P. Van Der Laan; M. Van Lent & L. Bibbe

With the statement above in mind, SFYN planned several field visits, followed by a semi-structured interview and a futuring assignment. The methodology will be discussed below, per section.

Field visits

After scoping the target audience, farmers were contacted through either SFYN's own network or with help of QuantiFarm Test Case manager. A list of seven farmers was made and visits were planned. Prior to the semi structured interview, farmers were asked to give the researchers a tour. The introduction and tour on the farm were also ment as 'warming up' for the visit, as we assumed farmers feel most at ease whilst showing them their farm, rather than starting with a conversation in a different setting than the farm itself.

[5] The QuantiFarm program has both farmers with and without technology. The process of SFYN selecting a target audience was before farmers without technology in the TCs were known. Furthermore, because of the shorter amount of time, SFYN focused on Dutch farmers only.

Figure 26 Field visit farmer in Ossendrecht, NL on 21.04.2023

Semi-structured interviews

During one of the workshops, SFYN worked with experts in the field of innovation consultancy and attempted to reframe both the problem and possible solution (Hekkert & Van Dijk, 2011). Through this, SFYN was able to sharpen their goals of this additional research and supported the semi structured interview protocol by formulating clearer questions.

A few examples of the interview protocol's focus are type of farm (biological or not); the relationship with family (e.g. succession, role of family members); DATs usage yes or no and enjoyment in work (hedonic motivation). These questions were formulated, based on the UTAUT2 model (Venkatesh, Morris, Davis, & Davis, 2003) as guidance.

Futuring Techniques

Futuring techniques attempt to "*shape the space for action by identifying and circulating images of the future, a process by which relationships between past, present and future are enacted"* as explained by Anderson et al., (2010). With this techniques, actors are enabled to be engaged with images of the future and to shape opportunities in their current situation.

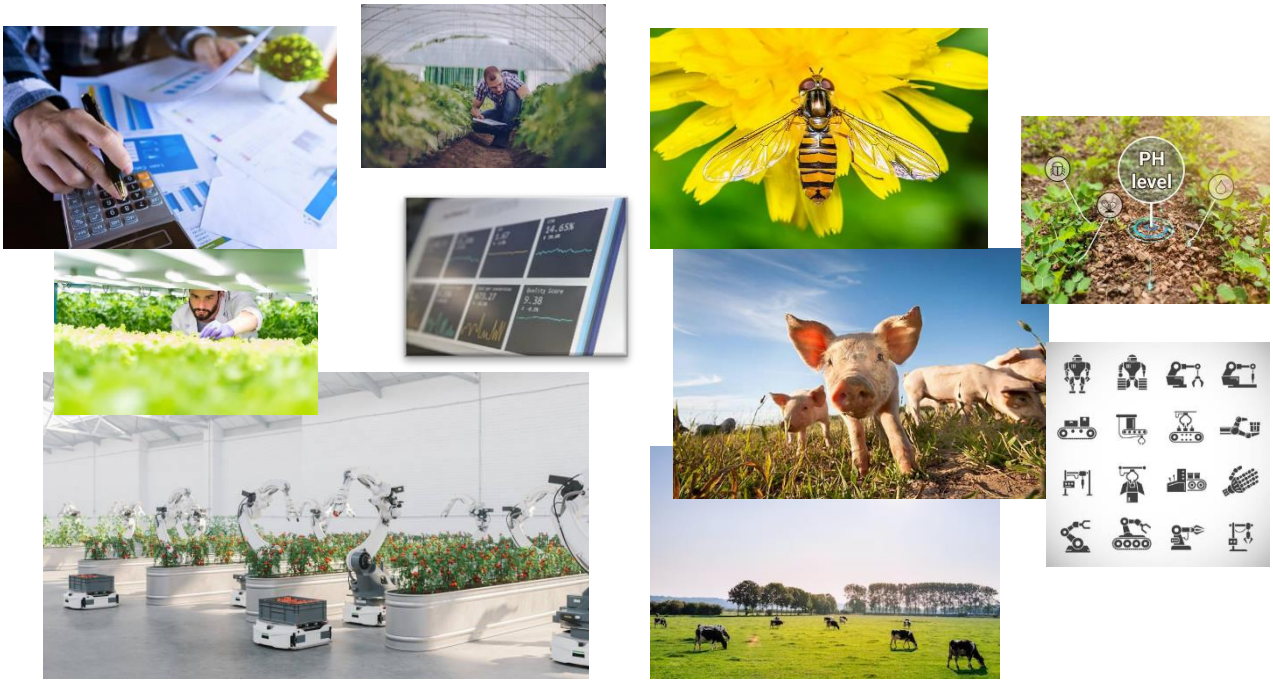
Applied to this research, SFYN collected images which represented either a data driven farm or a non-data driven farm.

Figure 27 Futuring technique during farm visit 21.04.2023 in Ossendrecht, NL

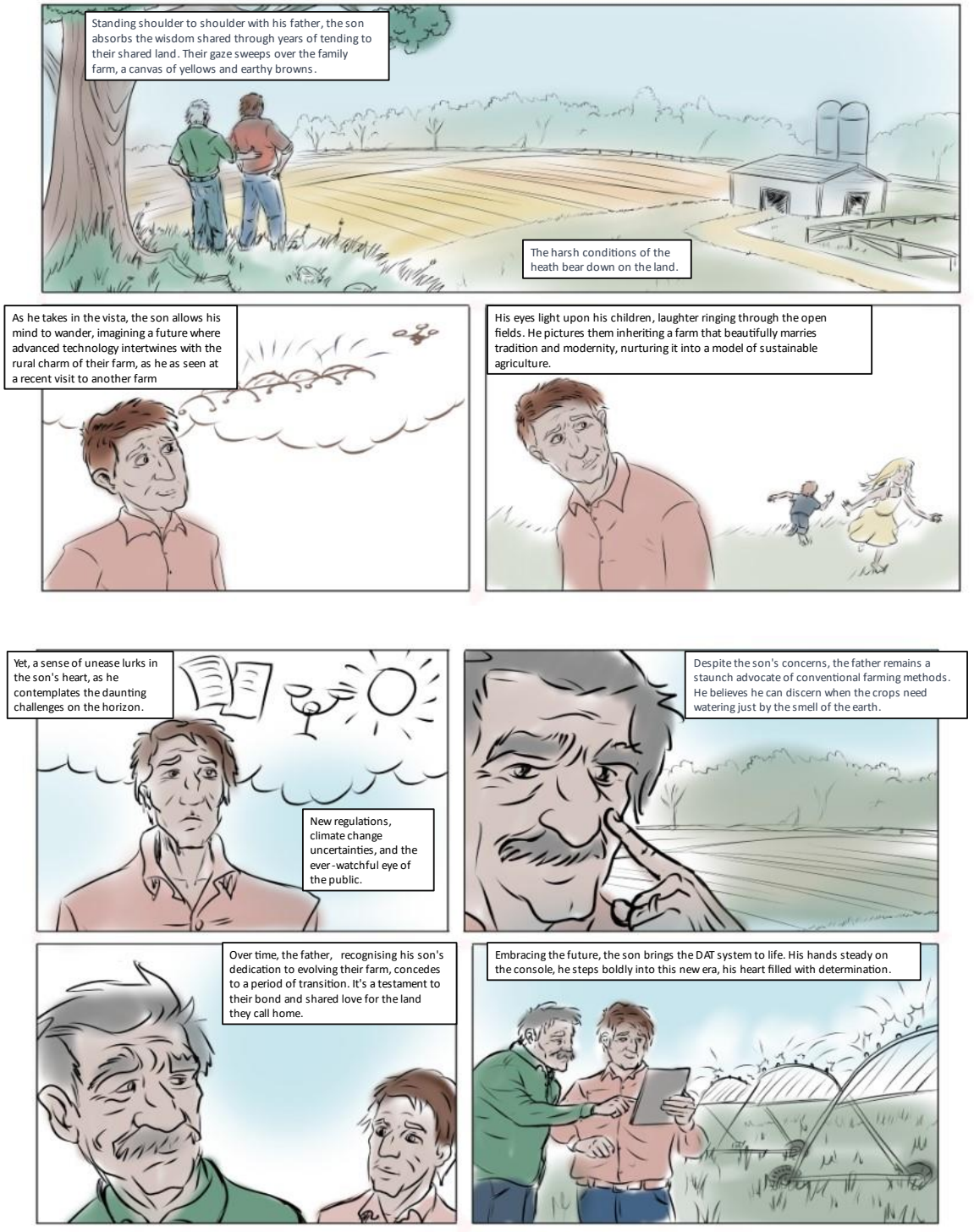
After the semi-structured interview, the farmer(s) were asked to display their future *farm of their dreams*. Here, farmers were instructed to select images from a total of 30 (see next section) representing their future farm in an ideal situation. Also, they were asked to motivate their choice. Notes were taken during this assignment and integrated into the summary presentation (see chapter 3.3).

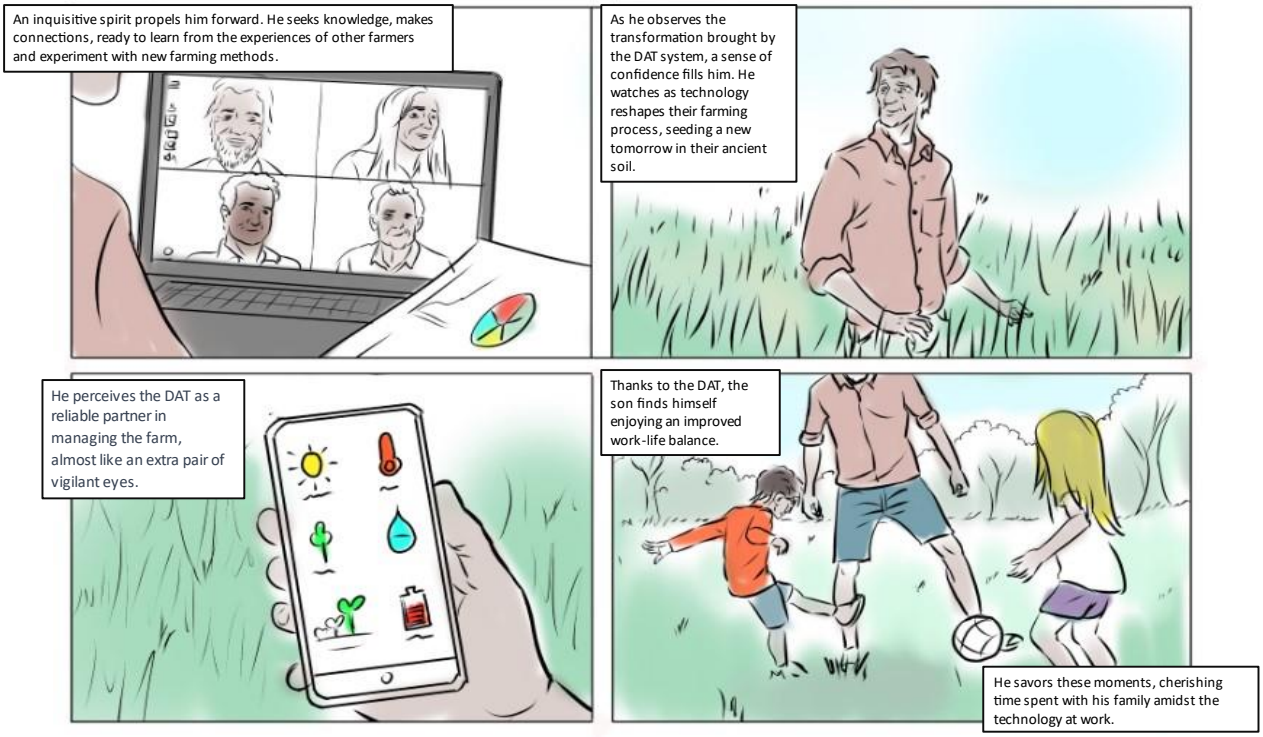
Futuring exercise

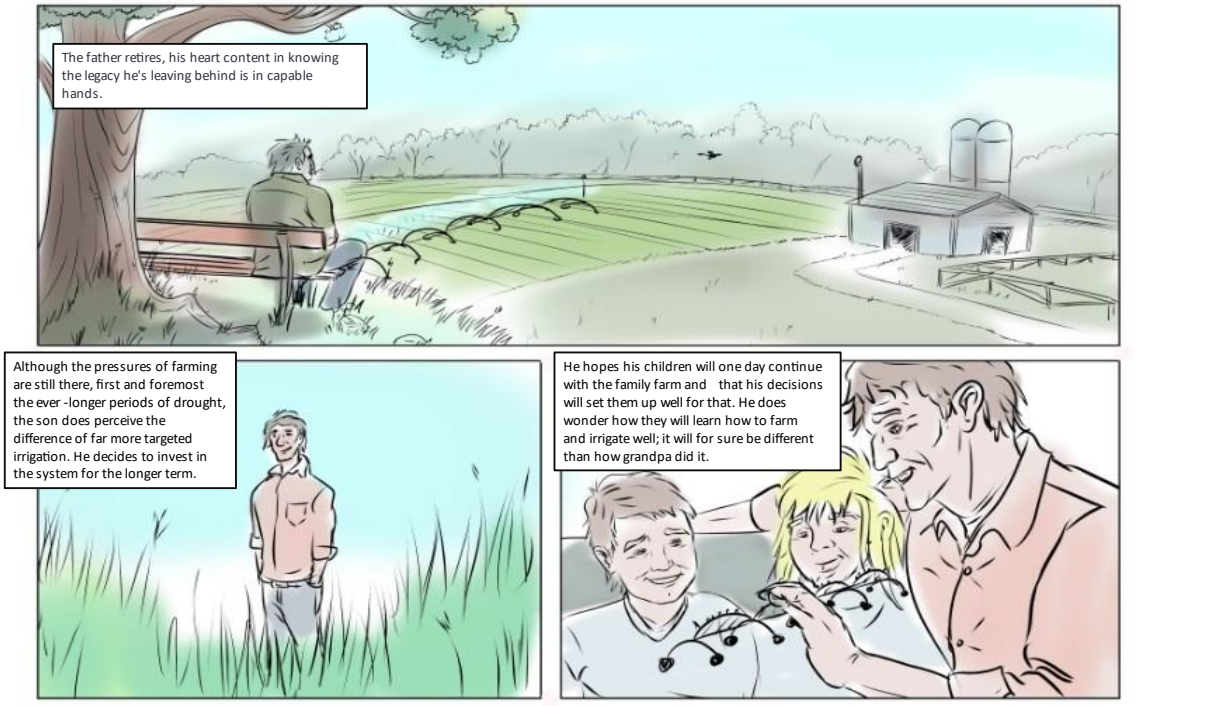
For the futuring exercise, images were used being either very technology focused or non-technology focused. Underneath, a selection of these images is displayed.



Appendix D – Storyboard of farmer 1: securing the legacy through digitalisation




An inquisitive spirit propels him forward. He seeks knowledge, makes connections, ready to learn from the experiences of other farmers and experiment with new farming methods.
As he observes the transformation brought by the DAT system, a sense of confidence fills him. He watches as technology reshapes their farming process, seeding a new tomorrow in their ancient soil.
He perceives the DAT as a reliable partner in managing the farm, almost like an extra pair of vigilant eyes.
Thanks to the DAT, the son finds himself enjoying an improved work-life balance.
He savors these moments, cherishing time spent with his family amidst the technology at work.


The father retires, his heart content in knowing the legacy he's leaving behind is in capable hands.
Although the pressures of farming are still there, first and foremost the ever -longer periods of drought, the son does perceive the difference of far more targeted irrigation. He decides to invest in the system for the longer term.
He hopes his children will one day continue with the family farm and that his decisions will set them up well for that. He does wonder how they will learn how to farm and irrigate well; it will for sure be different than how grandpa did it.