D1.2: Behavioural Determinants for DATS Adoption - final version

D1.2: Behavioural Determinants for DATS Adoption - final 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	01 July 2022
Duration	45 months
Author(s)/Organisation(s)	Caroline van der Weerdt, Sabine Verdult, Julia Broderick-Hale, Dianne van Hemert / TNO
Contributor(s)	Lisa Parce / Teagasc, Francesco Parigi / POLIMI, Dionysios Solomos / GAIA
Work Package	WP1 – Behaviour Innovation & Stakeholder engagement
Delivery Date (DoA)	M29
Actual Delivery Date	29/11/2024
Dissemination Level	Public Usage
Abstract:	This report describes the research activities and outcomes of the behavioural work in QuantiFarm. In the first phase of WP1 (M1-M12) Test Case farm visits, surveys amongst QuantiFarm DATS adopters and non-adopters, and a specific research into non-DATS-adoption were undertaken, resulting in an integrated framework of DATS adoption (outlining both the decision path of DATS adoption and related behavioural determinants). Also, farmer stories are created to vivify the found data. In the second phase of the project (M12-M29) additional research was undertaken to gain a deeper understanding of possible determinants at play, i.e., gender factors, the interplay between technology and autonomy, and cultural factors. This research, findings, and resulting refinements of earlier work are added to this deliverable.

Document Revision History			
Date	**Version**	**Author/Contributor/ Reviewer**	**Summary of main changes**
01/06/2024	v0.2	TNO	Table of Contents
01/09/2024	v0.7	TNO	1st complete draft version for peer review
13/11/2024	v0.8	POLIMI, Teagasc, GAIA	Feedback provision
29/11/2024	v1.0	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. 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

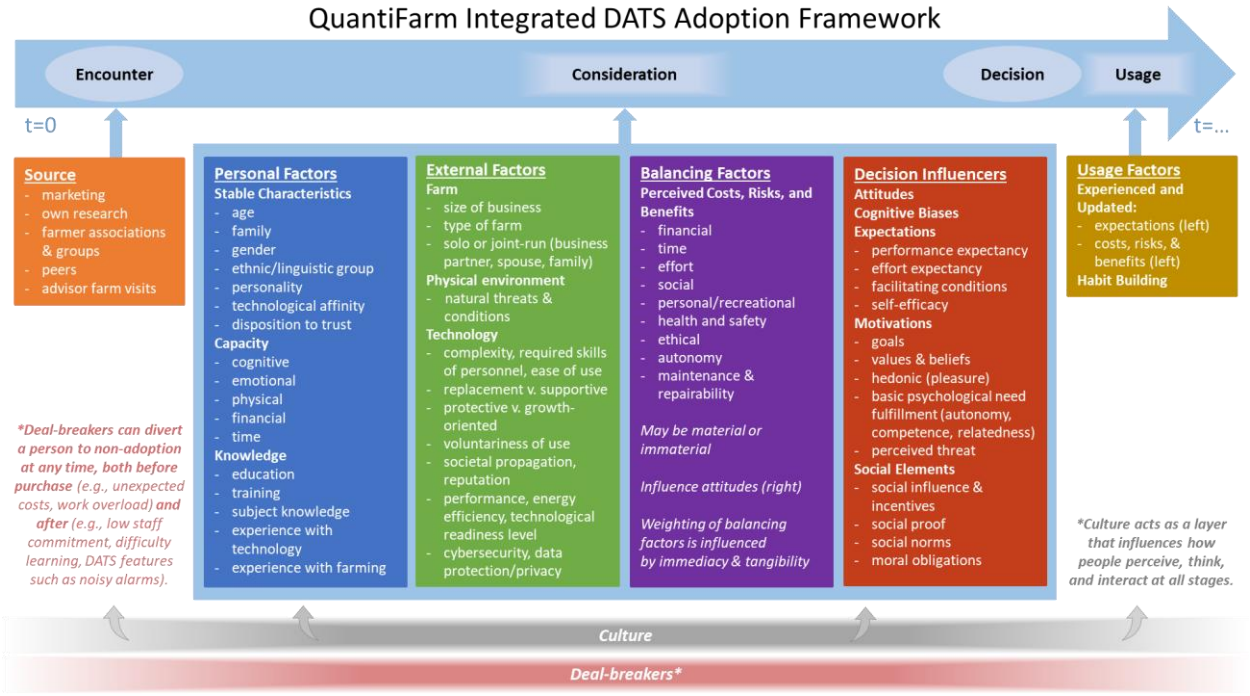
Executive summary

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

The first phase of QuantiFarm Work Package 1 focused on building a solid research body around the behavioural determinants of DATS adoption. Afterwards, deep dives into three topics that were distinguished as particularly relevant for DATSs adoption (i.e., gender; autonomy; culture) were conducted. To this end, several activities were undertaken:

- A broad literature study on technology adoption, DATSs adoption, and farmer decision-making;
- Test Case farm visits to 15 of the 30 QuantiFarm Test Cases;
- 2 surveys amongst the whole Test Case population, one for DATSs adopters and for DATSs non-adopters;
- A separate study on non-adoption outside of the QuantiFarm population, to gain more understanding of our wider audience;
- Three deep dives on gender differences, autonomy and technology, and culture to understand how these relate to DATS adoption specifically;
- All our research findings together, resulted in a novel framework that connects both the adoption process of DATSs with the determinants present during this process (this framework is elaborated upon in chapter 4 of this deliverable):

QuantiFarm integrated DATS adoption framework



To make this collection of data come alive, five farmer stories have been created of anonymous archetypes. These archetypes are generalised representations of farmers (with certain traits, in certain contexts), yet they very much inspired by 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 determinants in the integrated framework, ranging from farm and family factors, to attitudes, worries, motivations and experiences. They include a story on securing the farm legacy through digitalisation, a story on digital autonomy, a 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, this deliverable has served as a reference work for the development of comprehensible guidelines (in a separate document) for all partners and stakeholders and is intended to serve others working in related fields, united in their ambition to support farmers in their decision-making process and adoption of DATSs.

Table of Contents

Table of figures

1. Introduction

1.1. Project summary

The QuantiFarm project focuses on supporting the further development of Digital Agriculture Technology Solutions (DATSs) 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, DATSs 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 Agriculture Technology Solution (DATS) adoption in agricultural practices, in order to understand why and how DATSs 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 DATS adoption. In the end, this knowledge of DATS adoption is fundamental to develop behaviour intervention recommendations that can enhance DATS uptake; a main goal of the QuantiFarm project.

To collect the needed insights, different types of research have been conducted in WP1 (literature study; surveys; 23 farm visits; a non-adoption study; and specific deep dives on gender, autonomy and culture) and discussed with the QuantiFarm internal and external stakeholders. All our research, and the outcomes, are further explained in chapter 2 and 3. The resulting findings on behavioural determinants have been integrated with the findings on farmers’ decision-making processes, together leading to the integrated QuantiFarm framework of DATS adoption of chapter 4. This framework helps to recognise specific ‘threads’, here called ‘farmer stories’, describing how, step by step, DATS adoption comes

about. 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.

Next to this reference work, WP1 translated the findings into guidelines for creating interventions in such a way that DATSs uptake in the EU can be supported: from informed behavioural interventions to smoothen the adoption process for advisors; to how tooling is being set-up (in cooperation with WP3), and how policy makers can design scaling programs (in cooperation with WP5). An introduction to these guidelines is given in chapter 5 of this deliverable; the guidelines themselves are provided separately in document QuantiFarm_WP1 Guidelines DATS adoption via the QuantiFarm website.

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). The chapter concludes with the research approach of the extra research deep-dives that were conducted in 2024.
- **Chapter 3** outlines the determinants found in the QuantiFarm project itself will be outlined, per research activity outcomes. This includes determinants based on Test Case visits and surveys.
- **Chapter 4** goes into the resulting “Integrated DATSs adoption framework” in which all found determinants are comprehensively clustered.
- **Chapter 5** introduces the consequent stories of farmers that connect these determinants to actual decision-making and practices on the farm, to vivify the found data.
- **Chapter 6** introduces the guidelines that were created based on this deliverable.
- **Chapter 7** serves as a comprehensive conclusion to the work in this deliverable.
- **Chapter 8** contains the overview references we utilised in the research process.
- **Chapter 9** lastly contains appendices for background information in the content.

2. Approach

2.1. Research approach in QuantiFarm

An important driver of the design of WP1 activities was the awareness that earlier research on DATS adoption was, albeit highly relevant, often based on either questionnaires or structured interviews (e.g., this is the case in many of the references of chapter 7). These methods 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 many factors influencing DATS adoption as we could, we chose to employ a more observational approach first. This was then followed by surveys, to get a feel for which findings from the observational study we could generalise to the wider population.

For the deep dives in the second phase of the behavioural research of WP1, we visited (mostly other) Test Case farms and farm sites outside of the project to conduct semi-structured interviews focused around three main topics: gender, autonomy, and culture (expanded upon in section 2.1.5 (deep dive approach), 2.2 (deep dive literature), and 3.2 (deep dive outcomes). These deep dives allowed us to get more qualitative insights into these topics that showed up as relevant earlier, and get a feel for how these topics are connected to DATS adoption.

Furthermore, QuantiFarm adds to the existing knowledge base of previous research on DATSs in a few ways:

- Concerning the objective and design of the project:
    - The objective is to support the further deployment of those DATSs 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 agriculture technology solutions;
    - By 'adoption', we chose to follow a definition tailored to the QuantiFarm project: adoption of a DATS in our case means that the DATS 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 DATS is not a binary yes/no decision, but rather influenced and shaped by many factors during a longer time span;
    - We sharpen our results by giving specific attention to non-adoption to provide a deeper and more balanced view on DATS adoption;
    - 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 DATS 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 that a dialogue can take place in a trusted environment and thereby increase the chances that meaningful stories of adoption (with uncertainties, attitudes, etc.) are expressed. It also gives researchers a better understanding of the context in which farmer decision-making takes place. 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 their 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 served the dual purpose of creating a safe and comfortable setting to speak freely, and of allowing us to get an idea of the more informal processes, habits and family influences on the farm, all of which 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 two separate documents (the Reports on Test Case visits on the QuantiFarm website).

A second round of TC visits, and also visits to farms outside of the project, was conducted at a later stage of the research. These visits are described separately to most accurately illustrate that they served a different purpose (i.e., delving into the deep dive themes that emerged from the findings of the first round of TC visits and from the survey results). In total, 23 farm visits have been conducted all over Europe (Portugal; Spain; Italy; the Netherlands, Belgium; Germany, Ireland; Finland; Greece; Croatia; Romania).

In this deliverable, all aggregated findings are elaborated upon in chapter 3.

2.1.3. Surveys

Given the goal of the project to support the uptake of DATSs 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 DATS 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 DATS on the farm is perceived. The whole survey can be found in appendix B. The survey was filled in by 24 Test Cases and 40 farmers (some TCs have more farmers working with the DATS 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 employ the assessed DATS. 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 DATSs, 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 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 D. The outcomes can be found in chapter 3.4.

2.1.5. Deep dives

The findings from the previous phases of the research (i.e., literature study, test case visits, surveys, and additional research on non-adopters) gave us a general overview of the literature on technology adoption in agriculture, provided insights into the population of farmers, including non-adopters, and showed gaps in the knowledge on behaviour innovation in agriculture. These results supplied the basis for the second part of the research and highlighted the need for addressing three gaps in the knowledge through a series of so-called deep dives, i.e., gender, autonomy, and culture.

- Gender came up from the test case visits, where the interactions between men and women on the farm (usually as the farmer and his wife) raised questions about work divisions, opportunities for women, and decision-making responsibilities.
- Autonomy was an evident theme throughout: for istance, the focus on self-reliance in the conversations with farmers, and the survey results (see chapter 3) that point towards a preference for DATSs that are not fully autonomous, motivate an extra study into this topic.
- Culture is an obvious choice for a deep dive, as a European project inherently includes different countries and cultures.

The three deep dives were undertaken in a series of steps. First, background research was gathered by reviewing findings from previous phases of research and by scanning the literature. Then, farm visits were planned with 14 farms across 6 countries. These visits were conducted as semi-structured

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

interviews in order to lead the conversation along the three topics while still leaving ample room for spontaneous input and observations. We prepared for the semi-structured interviews by sending out a pre-visit questionnaire and integrated elements of a behavioural coding protocol (Malik & Lindahl, 2004) and relational mapping. These approaches are briefly explained below.

Semi-Structured interviews

Semi-structured interviews (SSIs) are a robust, qualitative research method well-suited to situations where closed questions alone may be insufficient to achieve in-depth insights (Adams, 2015). Compared to more structured interviews, SSIs use probing follow-up questions (such as *how* and *why*) to maximize understanding of the respondent's experience, and they allow the conversation to wander naturally to capture topics relevant to the respondent rather than those prescribed by the interviewers (Adams, 2015). They are especially suitable in situations where respondents might not feel comfortable speaking candidly in front of others, where the aim is to understand "independent thoughts of each individual in a group", and where the particular subject matter is relatively unexplored meaning that freedom to explore new leads that may emerge is highly valuable (Adams, 2015).

The current study matches all three characteristics, which motivated the choice of SSI as one of the methods utilised. Our SSIs included both a dyadic ("duo") interview as well as individual interviews with each of the repondents. The decision to interview the dyad individually was made due to the sensitivity of some of the topics, such as gender and relationship dynamics (e.g., in relation to joint decision-making). It was imperative to create an opportunity for both people not only to speak freely, but also simply to have their own 'airtime' in case one was more talkative. It also allowed each repondent a break to avoid fatigue, which was critical in such a long interview.

Pre-visit questionnaires

Approximately two weeks before each deep dive TC visit, a short questionnaire was sent to be completed by both repondents. The questionnaire asked basic information (e.g., name, role on farm, relation to other repondent), logisitical information (e.g., will you be comfortable conducting the interview in English or Dutch or would you like us to provide an interpreter?), and a few questions on each deep dive topic. The questions were adapted from established measures for each topic. This provided us with a preliminary insight into the repondents but also served the important purpose of giving the repondents an idea of the types of topics that we would be discussing during the visits. The topics of gender, autonomy and culture are complex and abstract, and may well be unexpected in farm visits from an agriculture- and technology-focused research project. Therefore, for the success of the visit, it was beneficial to have the farmers expect such a discussion (also for deciding whether or not an interpreter would be needed). The topics were also front-loaded in our invitation emails for extra clarity.

Relational mapping

During the deep dive farm visits, we broke up the extensive conversation (semi-structured interviews) with a creative activity called relational mapping. In this activity, respondents use sticky notes to map out how they see themselves, their farm, their DATS, and other relevant people, things, and concepts as relating to each other. Where the participant places a sticky note in relation to another sticky note indicates something about the relationship they perceive between the two things. For example, if a farmer writes down their spouse's name first and places it overlapping with their "me" note, this would indicate perceived closeness and the spouse playing a bigger role in the farm "world" than a farmer who did not mention their spouse at all in this brain map and instead included only business-related ideas. As another example, a farmer who puts "the farm" above "me" might be feeling the burden of the farm upon them. This should not be guessed or assumed. Participants can explain their reasoning as they go, and researchers can ask questions. In the present research, participants started with three sticky notes:

"me", "the farm", and "technology". After that, they were free to write down any and as many other things (people, values, ideas, etc.) as they wanted on additional sticky notes and place them down too.

Relational mapping is a type of graphic elicitation technique. These techniques allow participants to create a visual representation of a concept (Copeland & Agosto, 2012), in this case their farm. This often helps participants to express complex ideas (Copeland & Agosto, 2012). The technique also helps participants to maintain their train of thought (because they can quickly jot something down then return to explain it later) and helps them to develop their ideas further because they can look at their map to spark new ideas, leading to richer data overall (Copeland & Agosto, 2012). This technique works well with semi-structured interviews because the combination of mapping and open questioning allows researchers and participants to ensure they are understanding each other correctly, generating more accurate and consistent data (Copeland & Agosto, 2012). For experimental control, sticky notes were placed down on a square cloth (approximately 90cm long and wide) provided by the researchers. This created the same "blank slate" for all respondents despite the fact that the interview locations varied greatly.

Behavioural Coding Protocol

On most farms, couples (usually husband and wife) work together to run the farm and their family. This requires complementing each other both in farm-related as well as family-related tasks, and making decisions together. In order to add depth of understanding of this relationship, we drew from a behavioural coding protocol to gauge the husband-wife interaction with each other. Such a protocol helps researchers to code, for example, how often one of the partners interrupts the other, how often they look at each other, and how often they finish each other's sentences. Behavioural coding protocols are used across different research domains, such as team functioning and relationship research. For our Test Case visits we made a selection from the System for Coding Interactions in Dyads (SCID) by Malik and Lindahl (2004). Although not all dyads in our study were married couples, the majority were. For those who were not, the coding protocol may still stand to offer insight into the close dyadic relationship between the two people and to broaden the scope of our attention and deepen understanding of the dynamic between the farm decision-makers.

Cultural analysis

The diversity of the countries visited during the deep dive research was considered in terms of their scores on Hofstede's cultural dimensions (Hofstede, 2022). While it can never be assumed that a small number of individuals represent their entire culture, this consideration at least implied that the research was not pre-emptively limited to an overly narrow national cultural sample. Nevertheless, the six countries visited (Spain; The Netherlands; Belgium; Finland; Ireland; and Romania) do a good job at representing the full range of the twenty European countries involved in QuantiFarm, according to Hofstede's dimensions. For example, on the measure of power distance, referring to the level of hierarchy that people in a country accept, of all twenty QuantiFarm countries, the highest and lowest scoring are Romania and Ireland, respectively. Thus, Romania is a country in which people are used to and accept high levels of hierarchy between, for example, a boss and subordinates, whereas Irish people prefer a more egalitarian way of working and communicating. Both countries were visited during the deep dives, meaning that data in this respect was as widely representative as possible. In all six dimensions, i.e., power distance, masculinity-femininity (more or less distinct gender roles), uncertainty avoidance (more or less risk averse), long-/short-term orientation (focus on future vs. present), individualism-collectivism (focus on self vs. group), and indulgence-restraint (more or less freedom for

enjoyment), our visited countries came extremely close to capturing both the maximum and minimum QuantiFarm country scores (if not actually being the maximum or minimum)[2].

2.2. General literature study

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

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) and systematic literature reviews compiling the evidence (e.g., Rizzo et al., 2023). 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[3].

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).

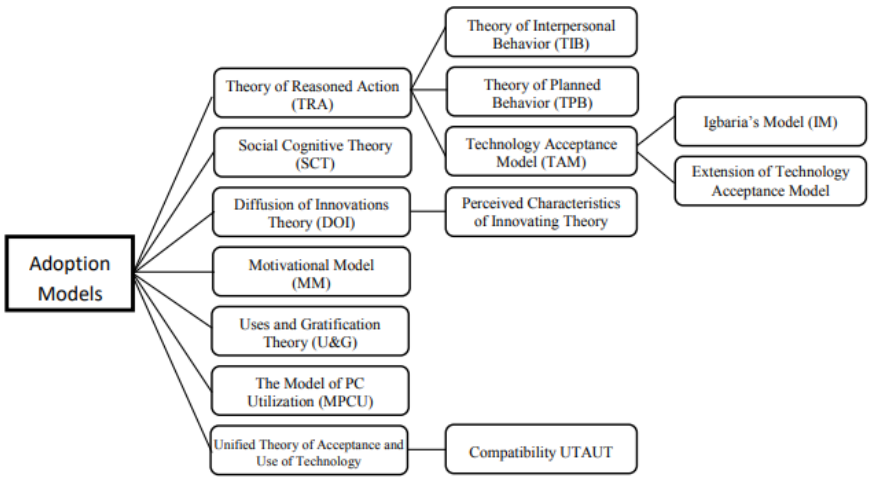


Figure 1: Adoption model overview (Taherdoost, 2018)

2 The range of scores of all twenty QuantiFarm countries versus of the six countries visited in the deep dives, respectively, are as follows: power distance: full 28–90, deep dives 28–90; masculinity-femininity: full 9–70, deep dives 14–68; uncertainty avoidance: full 35–112, deep dives 35–94; long-/short-term orientation: full 24–83, deep dives 24–82; individualism-collectivism: full 25–89, deep dives 30–80; indulgence-restraint: full 13–70, deep dives 20–68.

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

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 DATS adoption, too, such as social influences. We will thus elaborate a bit more on UTUAT below.

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

Although it is comprehensive and rather complete, UTAUT 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 DATS adoption. In the literature, we roughly distinguish a difference between precision-related technologies, and decision-support systems.

2.2.1. Precision agricultural technologies

Precision agricultural technologies (PATs) ensure “plants (or animals) get precisely the treatment they need, determined with great accuracy”[4]. 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.

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

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 DATSs, 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).

2.2.1. Decision support tools

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.

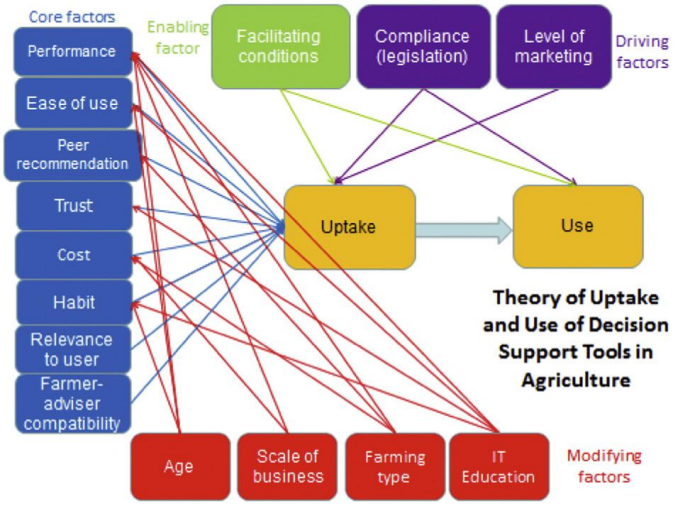


Figure 2 Theory of uptake and use of DST in agriculture. From Rose et al. (2016)

2.2.1. Digital agriculture technology adoption

As we have already concluded that DATS adoption is not a binary yes/no decision taking place in isolation, an important objective for WP1 is to capture farmers' experience of DATS 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 DATS 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 DATS adoption vary greatly, and the implications of how farmers actually come to a choice to invest in DATSs 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.

2.3. Literature study on deep dives

2.3.1. Gender

This deep dive focuses on disentangling the effects of gender on technology adoption among farmers. In general, men and women still face stigma and stereotyping in occupations traditionally dominated by the other gender, such as farming (Van Veelen & Veldman, 2020).

Social scientists have been addressing the disadvantaged position that women have in male-dominated domains, for example in the field of medicine, the energy transition and peacekeeping missions. Disadvantages for girls emerge from a young age and continue through adolescence and beyond (Mackin, 2006; Carter, 2014). Girls and boys are socialised in different ways, such that fewer opportunities arise for girls than for boys in, for example, STEMM (science, technology, engineering, mathematics and medicine) fields (Mackin, 2006). These sentiments – starting at the age of 6 years old - such as the construction that science is "for boys" and seen as "unfeminine" (Macking, 2006) - contribute to the gap between girls and their full potential. These differences impact the educational and career choices that girls/women make later on, illustrated by the statistic that only half the women who chose to do a beta study in STEMM stay in the field, meaning that the other half leaves the sector. Such cultivation occurs both private (home) and public (educational institutes) spaces and is harmful not only for girls and women, but also for boys and men (Clowes, 2013). Working to recognise, unpack, and mitigate the opportunities that girls and women miss over the course of their lifetimes due to our collective (unconscious) biases is essential, as doing so has the potential to enhance our society on social, economic, political and environmental levels.

It is not uncommon for certain fields to transition from being dominated by one social group—in this case, women—to being predominantly occupied by men. A notable example can be found in the history of programming, where women initially played a central role as "computers," performing complex mathematical calculations and foundational work in the field (Lockheed, 1985; Light, 1999) . Similarly, fields such as clerical work, teaching, and telephone operating were once considered highly suitable for women but shifted towards male dominance or greater gender parity as their perceived importance or professional status grew. Another example is the medical profession, particularly in the 19th century, where nursing was primarily women's work, while surgery and other high-status medical roles were dominated by men (Salles et al., 2019), a trend that persists in some specializations today (Lim et al., 2021). These shifts often reflect broader societal dynamics and the changing valuation of labor within these domains

This occurred also within agriculture, which is now thought of as masculine despite the fact that it was women who first cultivated and worked the land (Inhetveen, 1998). This discrepancy limits the conversation about women on the farm and their influence, then and now. Indeed, it is still debated whether the role commonly believed to be played by men was actually played (only) by men. Recent revelations about the hunter-gatherer theory, which focuses on the time before settling on one piece of land (farming), raised new questions about (gender) role division, when it was found that women actually made the first tools and also hunted (Anderson et al., 2023).

Another pattern seen within such shifts of dominated gender change, is that women are underrepresented in cultural stories. In fields such as STEMM, literature & arts and even in our street scene (think of statues) (Su & Rounds, 2015; Oliver, 2017; Nelson & Seager, 2008), men's contributions are not only portrayed more dominantly, but significant contributions made by women are, by contrast, overlooked (Schaffer, 2000; Tsjeng & Tsjeng, 2018; Jung & O'Brien, 2019).

Also, agriculture is still a male-dominated domain and, similar to the examples above, women were and still are overlooked (Brandth, 2002). Because of this, it is likely to assume that also in innovation processes women are unrecognised.

Such gender dynamics throughout the innovation process are prone to result in gender differences in the last phase of innovation, namely in technology adoption and in the actual usage of technological systems. These dynamics mean that innovation itself may neglect the full range of perspectives, resulting in an incomplete and less thoroughly thought-through process and product that serves all.

Although consensus about the influence of gender on technology adoption has not yet been reached (Rizzo et al., 2024), this deep dive sheds light on women and their role on the farm. In our results as discussed in the next chapter, we attempt to portray a more complete (gender) picture of the agrisector and how women experience DATSs.

2.3.2. Autonomy

In the first phase of the WP1 collection, it was identified that a farmer's sense of autonomy in relation to DATS adoption is an important theme. This inspired this deep dive topic. The research team noticed that farmers would comment that they enjoyed working for themselves and that they were frustrated by the government telling them how to run their farms. In discussions about technology, another emerging sentiment was that they know what is best for their crops and want to be in control of that (as opposed to having crop care decisions be automated). These comments indicate a common theme being placed upon personal autonomy.

Given the focus of WP1 on the behavioural and psychological determinants of DATS adoption, this research adopts a psychological definition of autonomy as one of the three basic psychological needs outlined by the well-known "Self-determination theory" (SDT). SDT conceptualises "basic psychological needs for autonomy, competence, and relatedness as innate and essential for ongoing psychological growth, internalisation, and well-being" (van den Broek et al., 2016). For research purposes and relevance, we will only focus on the need for autonomy.

A strong body of research has shown that the need for autonomy is universal, although there is also a selection of literature which suggests that there may be cultural differences in the degree to which people value autonomy (van den Broek et al., 2016). Satisfaction of one's need for autonomy increases intrinsic motivation and engagement, which in turn increase one's sense of well-being (Karimi & Sotoodeh, 2020). People who feel that they have sufficient autonomy (i.e., whose need for autonomy is met) tend to experience lower workload and fewer emotional demands (van den Broek et al., 2016). Two distinctions for this concept of autonomy should be made. First, the need for autonomy refers to the need to act with ownership and choice over one's behaviour (van den Broek et al., 2016). It does not necessarily mean choosing to act independently of the wishes of others; it involves having the psychological freedom and ability to choose how to act, whether the chosen behaviour is in compliance with the wishes of others or not (van den Broek et al., 2016). Second, our definition of autonomy refers to the basic psychological need and not to autonomous technology.

The Harvard Business Review (2023) made the recommendation to avoid targetting fully automated products to identity-motivated consumers. It also made the recommendation to communicate technology as a complement rathen than as a replacement, based on the finding that identity-motivated consumers had more positive attitudes to an appliance described as letting them use their skills than to an appliance described as handling the task completely. These recommendations are based on the principle that automation of an activity can be perceived as a threat by people who identify with that activity. This can be understood in terms of autonomy, in that a person's need for autonomy is satisfied by performing a task that they feel represents them (i.e., that they identify with) and that automation of this task would remove that sense of fulfilment.

2.3.3. Culture

As Quantifarm examines Test Cases across Europe, national, regional, and ethnic culture were important variables to take into account. As such, the culture deep dive was aimed at identifying cultural

aspects in DATS adoption[5]. Behavioural differences between cultures or countries are often described using the cultural dimensions by Hofstede (1980, 2001). He introduced six dimensions that can help to explain differences in the way people across countries work and live together:

1. Inidvidualism versus collectivism, i.e., more focussed on individual or group;
2. Power distance, i.e., more or less hierarchical;
3. Uncertainty avoidance, more or less risk averse;
4. Masculinity versus femininity, i.e., more or less distinct gender roles;
5. Short versus long-term orientation, i.e., focussing on past and present or future;
6. Indulgence, i.e., more or less freedom to enjoy and have fun.

In the domain of technology adoption, these dimensions have proven to be useful for making sense of differences between the ease and speed with which people, in this case farmers, adopt innovative technology. In general, technology adoption seems to occur more slowly in collectivistic societies, since social networks in those societies are more closed and contact with outsiders is not encouraged (Fogli & Veldkamp, 2019). In individualistic countries, on the other hand, individuals are encouraged to be more open to outsiders, think of new ideas, stand out, and take risks. Therefore, individualistic societies have more favorable attitudes towards technology and its adoption (Jayasekara & Fredriksson, 2021). Even when controlling for economic variables such as GDP, education and level of democracy, geographic factors (such as temperature and land lockin), and historical factors, the effect of individualism on technology adoption remains strong and positive. It should be noted that some studies do not show the relation with individualism and collectivism (Murcia & Whitley, 2007; Ryschka & Bick, 2013).

The distinction between individualistic and collectivistic societies resembles the distinction proposed by Lee et al. (2013) between Type I cultures and Type II cultures, respectively. This research shows that "in Type I cultures, innovation has a significantly higher level of effect on adoption than it does in Type II cultures; and in Type II cultures, imitation has a higher degree of effect on adoption than it does in Type I cultures. These findings imply that in individualistic cultures, people tend to seek information on their own from direct and formal sources, whereas in collectivistic cultures, people rely more on subjective evaluation of an innovation, conveyed from other-like-minded individuals who already have adopted the innovation." (Lee et al., 2013).

Research (e.g., Jacobs-Basadien & Pather, 2022; Jayasekara & Fredriksson, 2021; Syed & Malik, 2014; Zhang, Weng, & Zhu, 2018) was also conducted on the cross-cultural generalisability of the earlier-mentioned UTAUT model (2.2.1) across cultures: to what extent do the key factors play a role in technology acceptance in different countries? It turns out that UTAUT as a model holds across cultures, but the effect of each variable varies across cultures. This means that performance expectancy, effort expectancy, social influence, and facilitating conditions all influence behavioural intention, and consequently, usage behaviour, regardless of culture. However, depending on the degree to which a country is more collectivistic or individualistic[6], these variables are stronger at predicting behavioural intention, and consequently, usage behaviour. A summary of results from a selection of research papers is shown in Figure 3. On the top bar, European countries are arranged in terms of their relative score on the individualism versus collectivism dimension. In the bottom blocks, research results on the relation between cultural values (individualistic versus collectivistic) are presented. In general, the effects of effort and performance expectancy, as well as behavioural intention on technological use, are greater in more individualistic countries, such as the Netherlands, Ireland, and France, than in more collectivistic countries such as Romania and Greece. On the other hand, use of technology is more influenced by

[5] It should be noted that we did not address farmers as a cultural group.

[6] The difference between individualism and collectivism, is that individualism prioritises personal rights and freedoms, while collectivism prioritises group harmony and coherence. (Collectivism vs. Individualism: Similarities and Differences (2024) (helpfulprofessor.com)

social contacts and facilitating conditions in more collectivistic countries. This implies that stimulating use of technology in Romania or Greece should be more focussed on facilitating the process as well as contact between farmers, whereas farmers in the Netherlands or France would benefit more from an outline of what they can expect from the technology.

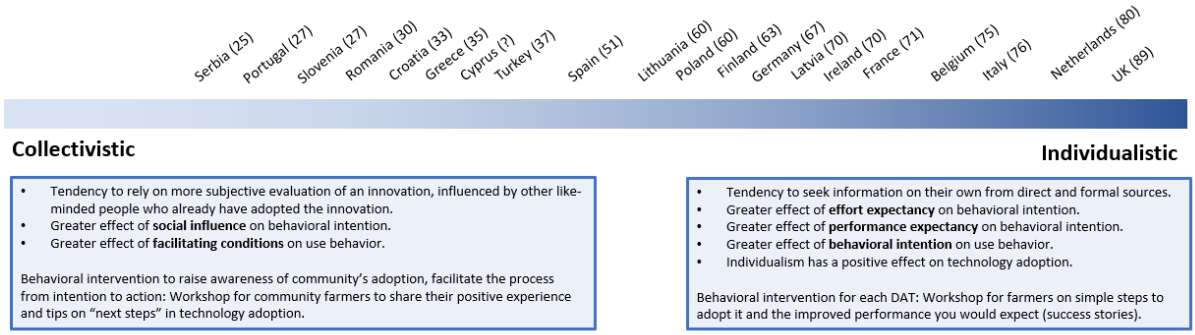


Figure 3 Country score on Hofstede's the Collectivism - Individualism scale

Syed and Malik (2014) included the other Hofstede dimensions in their study. They found that individuals from less hierarchical and more individualistic cultures are less influenced by social norms compared to more hierarchical and collectivistic cultures. Also, cultures scoring low on uncertainty avoidance (i.e., cultures that are more risk tolerant) tend to adopt new technology more even if support infrastructure for this technology is not extensive. However, cultures with high uncertainty avoidance look for more guarantees and assertions when adopting new technology (see also Jacobs-Basadien et al., 2022). This finding is very relevant in the context of DATS given the significant financial investment and complex risks and considerations that often exist for business and family in farming. Figure 4 shows an overview of the findings on cultural dimensions in relation to technology adoption.

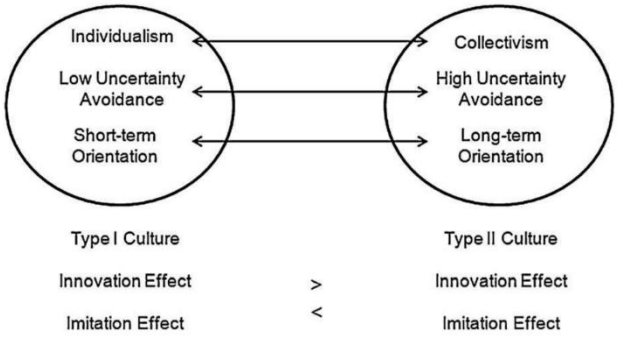


Figure 4 Cultural dimensions and technology adoption (Lee et al., 2013)

Some additional country-level variables can be expected to play a role in whether and how farmers adopt innovative DATSs. For example, cultural differences in trust (in particular, in the basis for trust) also impact the process of adopting or not adopting DATSs. Meyer (2016) distinguished countries where trust is based on confidence in another person's accomplishments, skills, and reliability versus on emotional closeness, friendship, and empathy. This has implications for how farmers come to adopt a new technology and for the role of the farm advisor in this process. A farmer who trusts another person based on skills, will probably readily trust an advisor who had extensive knowledge on a DATS, even if they do not know each other very well. On the other hand, a farmer from a country where friendship is needed in order to trust another person might need a more personal approach and get to know the advisor before trusting their expertise.

Also here there is a link with political history; in some countries, for example, former USSR countries, a certain level of suspicion toward outsiders was encouraged. In general, political history, specific

geography, and climate are all country-level variables that are expected to have an impact on how, when, and what farmers decide in terms of DATSs adoption.

3. Determinants of DATSs 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 phase 1

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 5 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 DATS they utilise supports in their work. The perception of how much value the DATS adds varies somewhat though; whereas all agree the DATS is a welcome extra pair of eyes, some state the DATS 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 DATS as a support system to bridge this information gap. The Dutch farmers (male, between 46 and 55 years of age) see the DATS 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 DATS 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 DATS 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 DATS can also be used for marketing purposes. The Portuguese farmer furthermore stresses how DATSs 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 DATSs 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 DATSs that is appreciated by all. The farmer, however, is still ultimately responsible for processing the DATS data towards action perspective.

Although regulatory frameworks greatly vary (which is remarked as a great barrier to DATS 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 DATS 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 DATSs 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 Test Case farm visits phase 2 (deep dives)

For the deep dives, data was gathered both through literature search and through farm visit. The next three sections report on the findings for each domain we researched, and the role that they play in DATS adoption.

This is the overview of Test Cases, complemented by a few farms outside of the QuantiFarm project, visited during phase 2:

Date of visit	Country	TC#	Interviewee relationship
Sep 2023 (live) & Feb 2023 (online)	Spain	3	Husband-Wife
12/03/2024	The Netherlands	/	Husband-Wife
13/03/2024	Belgium	24	Husband-Wife
13/03/2024	The Netherlands	/	Husband-Wife
14/03/2024	The Netherlands	/	Husband-Wife
15/03/2024	The Netherlands	/	Father-Daughter
16/04/2024	Finland	21	Father-Son
16/04/2024	Finland	21	Husband (wife absent)
28/05/2024	Ireland	26	Husband-Wife
29/05/2024	Ireland	26	Mother (daughter absent)
11/06/2024	Romania	10	Husband-Wife
11/06/2024	Romania	10	Agronomist
11/06/2024	Romania	17	Husband (wife absent) and DATS supplier
11/06/2024	Romania	28	Brothers

Figure 6 List of deep dives farm visits

3.2.1. Gender

Decisions on the farm are often made jointly and, as such, are subject to interpersonal dynamics, including gender dynamics. Designated to take care of the household, do the paperwork, take care of a secondary incoming cash flow and help out during high season (often alongside a paid part-time job), the spouse of the farmer is there. Although in many cases "she does not do anything physical on the farm" and/or "has no affinity with technology", she plays a significant role in the introduction of innovations to the farm.

Knowing that decisions are not made unilaterally, we endeavoured to find out how the secondary decision maker (our other respondent) plays a role in this. In most cases, this secondary respondent was the spouse (in all cases in our sample, the wife). In Ireland, she was even assigned a term to this, being the "laying hen". The term was described as a farmer's wife that "everyone knows in Ireland as the ideal partner for the farmer". She typically works as a teacher in primary school, giving her extended time off during summer season – also the busiest season on the farm –, as such being able to provide (unpaid) labour (described as "to help out")[7]. Other than terms, also other facets that facilitate the designated role of women in the agriculture are observed, from courses on "how to be a farmer's wife" to "driving a tractor for female farmers" and financial grants for Women in Agriculture (arranged on both national and EU levels). The fact that financial aid is being distributed in this way is yet more evidence that gender differences do exist.

7 The "laying hen" complies to a so-called HEED role (health care, elementary education, and the domestic sphere) (Croft & Block, 2015; Block et al, 2019), described as a role to be perceived of less value than roles in the STEM sector (male dominant).

Key outcomes from our findings are the different gender roles across countries. Generally, countries in the North and West of Europe endorse more egalitarian gender roles, whereas people in the South and East endorse more distinct gender roles. During farm visits, policymakers and/or DATS providers could take this into account, when discussing possibilities of a DATS. Furthermore, on family-led farms, the female is often responsible for the paperwork, meaning that digital portals and paperwork processes could be enhanced. In light of DATSs, service providers could thus consider working together with women more as end-users of possible DATSs, improving working conditions and job enjoyment. Lastly, the farms we visited and the roles women had or took on the farm were mostly smaller scaled in comparison to work the main operators (mostly male) did. Women's ideas on farming show a high affection towards sustainability, therefore, policies targeted at women should address this, rather than staging the more industrial nature of farms currently adopting DATSs.

More results from the deep dive on gender are described below, structured by means of categories, and illustrated by quotes from the interviews.

Tasks of women on the farm

At most visited farms, males were main operator of the farm, their spouses (all women) described their tasks as "doing the paperwork" and doing care work such as "taking care of the children". Other spouses had other tasks on the farm such as "running the farm shop" or other farm activities such as running the campsite and organising educational excursions for primary schools. None of these women explicitly mentioned their (unpaid) labour, yet this contribution was clearly observed.

In relation to the male dominated settings, such as the agricultural domain, a female Irish farmer (running the farm alone) outlines the following:

> *"I feel very unseen in the farm business. Not only because I am a woman, also because I pursue to farm organically. I always feel that I need to work twice as hard to be heard. We all know it doesn't have any benefits being a woman in this sector, why otherwise networks and spaces for only "Women in Agriculture" exist? If we were with many and without being framed as exceptional position, these clubs had no purpose."*

Feelings of being de-valued were shared by several other female repondents. Also, behaviour showed their own de-valuing of their role in the decision-making process of the farm. For example, whilst interviewing the Irish farmer, i.e. the male main operator of the farm, his wife occasionally jumped into the conversation, showing she was all up-to-date about the farmer's network and main stakeholders of important processes. At the same time, she left the conversation constantly to take care of the children and dinner. When asked direct questions, she either laughed or said that her opinion in this does not matter.

Devaluing oneself in this sense was a pattern observed in most of the spouses of male farm operators. Administration and work on the farm (either directly contributing to the production, such as harvesting in high season or other initiatives such as running the farm shop or farm camping) were not recognised as work. Also, taking care of the children and working in the household, which clearly means time and space for the male main operator of the farm to focus on tasks on the farm – were not recognised as labour.

The wife of the male farmer in Limburg described the division of work as follows:

> *"I studied and I grew up in the city. To learn about the agricultural sector, I decided to join a network group about farming. I did this in the evening, as I needed to take care of the household during the day. Once we got children, I could not pursue this activity and I was forced to stop the network club."*

An effect of such limited recognition stems from an example of a farm daughter who explains she does not want to join fieldtrips or networking events as they are "all male" and she does not want to be "that female who asks questions". This apprehension by women, as ones who do not have the knowledge, seems to be present, as well as a misfit in what is needed for social bonding. She explains:

> *"Everyone is at some point also drinking beer and it is the way for them to bond. I really want to go there for gaining knowledge, and by doing so I am normally not prone to ask questions. In these cases, I decide not to go, even though I will miss information and the opportunity to gain knowledge on the farming topic."*

Care work and unpaid labour

The wife of the Irish farmer works as a nurse in school, giving her "plenty of time to take care of the children as well, due to flexible working hours". The Irish farmer explained the concept of *the laying hen* as follows:

> *"We have a name for a wife who works in primary school: the laying hen. It is the perfect job to have because of the summer holiday. During that period, the wife is home to take care of the kids and to help out during harvesting high season. It is a well-known term in Ireland."*

During the interviews, this stereotype was found in different settings and across countries. The idea of the concept was confirmed by the Romanian couple running a farm together, stating that "a 14 hour workday does not leave time for women to take care of the household and the children", implying two things. First, that this assumed to be the role of women and second, that a woman having a job that leaves room for the secondary shift ('laying hen' phrase) is favourable. Also in Belgium, where the wife fulfilled a HEED role, she mentioned that summer holidays were great as she could be of help during high season of the farm. The same was repeated within the Dutch couple on the farm in the Zeeland province.

Decision making and technology uptake

In small decision-making processes on a day-to-day level – such as with known providers of the farm and business partners, the main farm operator (in most cases men) made decisions about the farm business. Women were in charge of domestic work, such as running the household and taking care of the children. In some cases, we heard that the amount of investment was sometimes a metric which in- or excluded the spouses from decision-making processes. As mentioned by a Dutch married farm couple:

> *"Anything above 5000 euros is discussed. Decisions below such investments are made by my husband. Such a strategy was also mentioned by the other Dutch married couple in Brabant, also a couple where the female spouse did not help directly on the farm."*

General technology usage, self-efficacy, motivation and tinkering styles

Of all male respondents, only one (out of 12) had a low self-efficacy in relation to technology usage (in comparison to the female respondents, of which 6 out of 7 mentioned to have low self-efficacy). Even though he does believe in innovation (thus technology) for a sustainable farming future, he himself was not interested nor felt qualified to be a technology user for his farm. All other male repondents (all farmers at their own farm) scored themselves medium on self-efficacy in relation to technology. Also notable were the tinkering styles, such as 'trial and error', a style mostly measured in men in comparison to a more 'apprehensive' tinkering style measured in women. Most of the male repondents indicated that they mainly used trial and error (8 out of 10), which is typical for men while most of the females said that they use self-education and research prior to usage. This would assume women have a higher information need during the adoption process of a DATS.

Social narratives of farming, its origin and effect

Men dominate the agricultural sector. This was not only validated by both men and women in how they say to divide responsibilities in their farm and marriage, but also by who was designated as the successor. A phrase much heard throughout several interviews was: "my wife does not want to be involved in these type of things", implying it is a man's task. Also, through observing the couples during the interview, we found that it was in most cases women who took care of the children while men were being interviewed.

An effect of the persistent narrative in which male dominate this sector, was touched upon by the daughter of one of the farmers. A farm daughter interviewed in Brabant, successor of her father's farm and already working in the farm company, is reluctant to go to field trips and network events, organised by the local farming community. Such groups exclude women constantly, she mentions. In cases she did go, she experienced her being the exception and outlier of the group:

> *"The farmers bond by male-specific social activities, such as drinking beer together. I want to gain knowledge but every time I ask a question, I feel uncomfortable."*

Women and (organic) farming

All women with a more explicit role of future planning, or managing the farm itself, have two things in common. The first being farming activities taking place on – relative to the other farms – a small scale. Second, farming organically was prioritised highly. One female farm operator runs her farm organically. The spouse of another farmer who does not play a role on the farm but does, sometimes, participates in decision making, dreams of having sustainable farming such as forestry farming, nature inclusive farming and organic farming as part of their farm business.

Both Romanian female farmers and the farmer's wife of the Belgian farm ran the orchard. In theory, this is also part of the farm and its production, however, it was not mentioned or recognised as a contribution to the farming business.

The self-evidence of such dynamics (women dealing with the orchard and men with the production on the farm) is observed in broader gender-stereotypical situations; taking care of the household is seen as obvious, whilst it is significant (unpaid) labour that makes it possible for the men to work on the farm. The same pattern is seen in most women taking care of administration, probably using technology of some sort to collect, save and analyse the farm figures.

3.2.2. Autonomy

A particular outcome from the DATS adoption surveys (chapter 3.3) points towards a preference of farmers for a DATS to ideally be relatively autonomous (for instance attain more of a 'co-worker' status), but should not become totally autonomous as farmers want to retain a degree of control over their operations. In other words, there seems to be a hestistation towards full autonomy by DATSs. This notion formed the basis for this deep dive on autonomy.

The theme of autonomy struck more of a chord with some farmers than with others. When explicitly asked "is autonomy important to you?", there were two general categories of responses. Some repondents were not particularly affected by the question and answered to the effect that autonomy was 'somewhat important, like for most people'. Other repondents, by contrast, immediately responded with great enthusiasm (and, often, a knowing laugh) that, yes, this really describes them. Interestingly, the enthusiastic response was usually shared between both repondents (when interviewing the couple), indicating that the trait was noticeably strong and the topic was relevant to the duo. Autonomy was often linked to hard work through a sense of satisfaction with one's actions, as illustrated by one farmer's observation:

"Hard work is rewarding and it gives you autonomy. It is a way of life."

Feelings of autonomy were most commonly limited by the increasing government regulations and paperwork. As mentioned by Spanish respondents:

"Lately, Spanish farmers have been protesting again due to our overload of paperwork and bureaucracy. We have so many things to fill in that the attention shifts from our land to the desk."

When asked whether they believed technology facilitates or interferes with their sense of autonomy, there was a strong consensus among respondents that, depending on how it is used, technology increases autonomy satisfaction. There was a recurring theme among the farmers that technology has much to offer in terms of helping them better understand their land. As one of the respondent said:

"I like looking at pictures from above taken by a drone, and comparing these to other seasons and years. This way, I can keep track of how the soil is doing and how crops grow. Understanding this helps me in my decision making on all sorts of things, such as what crops grow well and how to arrange my irrigation systems."

Many of the benefits of DATS that respondents reported can be understood as satisfying the need for autonomy. In some examples, benefits that were reported by respondents are related back to decision-making factors from the Integrated DATSs Adoption Framework (chapter 4) including basic psychological need fulfillment (in this case, the need for autonomy) and other factors. For instance, one respondent felt that the information from DATSs empowers him to make better, more autonomous decisions about how to grow their crops (*i.e., gives them autonomy over their farming process; related to behavioural determinants autonomy satisfaction, self-efficacy expectation, knowledge, etc.*). Another respondent felt that the information allows him to adjust the upcoming work schedule to suit environmental conditions and empowers him to have more time off to do what they want (*i.e., gives autonomy over the time and work-life balance; related to behavioural determinants autonomy satisfaction, family characteristics, goals, value motivations, etc.*). Another respondent saw a DATS as a tool for approaching his ideal way-of-working and for having his actions express his true self and values, for example, by improving working conditions, conditions for their animals, or climate friendliness (*i.e., gives them autonomy in terms of value enactment; related to behavioural determinants autonomy satisfaction, value motivations, moral obligations, etc.*). These benefits could be interpreted simply as the respondents' priorities or points of pride, but they can be more deeply understood by recognising their positive effect on autonomy satisfaction. Given that satisfaction of the need for autonomy is known to improve motivation and well-being, it is worth examining how DATSs can play a role in improving farmers' autonomy satisfaction, especially given the extreme demands of the industry.

The theme of autonomy also emerged in many other comments heard during the deep dive farm visits, indicating how autonomy may be a driver for DATSs adoption:

- *The government offers subsidies to try to influence which crops we grow, but I look at all my options and make my own decisions. I am proud of that.*
- *The repetitive paperwork and specific regulations frustrate me. I want to be out, working with my animals.*
- *I don't like to be told what to do. I'm reluctant to follow these new rules because I know my land. It was passed down to me and I won't change everything.*
- *When demand for our old products was low, we changed our products and got into processing as well. That put me back in charge.*
- *The bureaucracy at my corporate job drove me crazy. Nothing ever got done. Here, I can see my accomplishments.*

- *I like experimenting with innovative methods of pest control because it gives me the tools to run the farm I want successfully in the future.*

Referring back to the apprehension indicated in the 2023 surveys, farmers do experience elements of more autonomous technology that may infringe exactly this autonomy satisfaction, such as:

> *I chose a semi-automatic milking machine because this way I am still involved in the milking process and ensure a smoother transition that's better for my cows.*
>
> and
>
> *Technology gives me control. I use the technology; it does not use me.*

This does not interfere with the above-mentioned comments, rather it complements them. Autonomy satisfaction takes place when the farmer remains in charge, and the DATS is a means to support that. Whenever a DATS is destined to take over in area where a farmer finds satisfaction in autonomy, is where friction can arise.

All in all, taking one's need for autonomy into account, as well as how a DATS may incluence it, is likely to be of value when considering DATSs adoption. Is the farmer feeling the weight of a constrained sense of autonomy or are they content with their autonomy? Is autonomy very important to them or not something that resonates especially strongly? What goals and frustrations of theirs could be related to autonomy on a deeper level? Understandably, people rarely describe their goals and frustrations as "autonomy-related". Therefore, it is helpful to have an awareness of autonomy as a potential underlying "root cause" and keep up an antennae for comments that could indicate a need for autonomy. This awareness can help illuminate underlying motivations and foster better understanding of what should change, and what not, in order to create a more efficient and fulfilling farm (life).

3.2.3. Culture

Cultural aspects of technology adoption among farmers are intuitively relevant when thinking about different levels of innovative technology in, for example, a Swedish versus a Polish farm. The stereotype goes something like this: northern European countries have cultures that are more conducive to innovation (e.g., higher education of the population, more government expenses on innovation) than eastern European countries (e.g., more focused on traditional ways of doing things, lower GDP). Although there is a difference in level of education, GDP, governmental expenses on innovation, and a focus on traditional values between the two countries, this does not necessarily mean that random Swedish and Polish farmers behave in line with their cultural background. As such, the farm visits across different countries can be deceptive: differences between farmers in technology adoption and related factors can be attributed to culture, but also to personality, circumstances, type of farm, and a host of other variables outlined in the Integrated DATSs Adoption Framework. Still, farm visits allow for in-depth conversations that zoom in on mechanisms that underlie technology and that probe cultural patterns that the farmers/respondents observe in their vicinity/community. Therefore, the following insights do not necessarily concern clear cultural differences between farmers, but rather ways in which culture can interact with other factors, such as family circumstances, personality, and farm characteristics.

During the farm visits, we asked farmers how they would describe farmers of their own nationality compared to other European farmers. In addition, we discussed with them whether there are any cultural factors in their country that makes EU policy ineffective. Some questions were about cultural dimensions, such as individualism versus collectivism (When making decisions, how much does it matter what those around you think? Do you value independence or the needs and goals of those around you more?), uncertainty avoidance (Do you embrace uncertainty and see it as an opportunity, or do you

avoid uncertainty and prefer a more predictable outcome?), and power distance (Are you comfortable when there is a hierarchy (A system where people have different levels of authority or do you prefer an egalitarian structure?). Also, questions were asked about the basis of trust (When you are building trust with a new partner or colleague, do you do this by demonstrating that you successfully complete tasks and responsibilities or by building a personal connection?).

Through all cases, personal autonomy was a relevant thread. As mentioned in the previous paragraph, the need for autonomy is universal (i.e., not culturally-dependent) but the strength of how it is needed or desired does show cultural differences. We could not confirm or discard those cultural differences, because of the limited number of cases, but we can confirm the universal need for autonomy across cultures.

Another culture-related theme across all cases (i.e., related to the masculinity-femininity dimension) was in the expression of compatibility between partners. The compatibility in terms of roles, tasks, and personalities was discussed during all farm visits, and was a given across farms and countries. At the same time, in line with the masculinity-femininity dimension, cultural differences in gender roles and how they are compatible might play a role here. For example, farming is a male-dominated industry, making it harder for female farmers to find their place among other farmers, and encouraging traditional male-female divisions of labour.

Also, economic factors seemed to play a crucial differentiating role. The Gross Domestic Product (as an indicator of wealth) and the distribution of resources, influence how farmers work and live. For example, wealthier countries are generally more technology focused, facilitating DATS adoption for individual farmers. This became evident in the farm visits.

Attitudes towards migrants are related to this, and they play a role in how farmers do their work. For example, in countries with a more hesitant attitude towards migrant workers, such as Romania, DATSs may be appealing as they can help to manage the farm with fewer employees.

Wealthier countries are generally happier as a whole, though this does not say much about individual happiness. In addition to more contentment, there also seems to be more identification with tech savviness. This was reflected in the farm visits, in particular in the Netherlands and Finland.

In countries with a larger discrepancy between urban and rural areas, farmers may feel less connected to governmental policy, having effects on their senses of autonomy and trust. As mentioned before, it is well-known from research on cultural differences in trust that the basis for trust can differ across countries (Meyer, 2016). For example, in southern-European countries such as Spain and France, people are more likely to trust others when they know them (either directly or indirectly), as opposed to norther-European countries where trust is more based on the practicality of the situation and somebody's role (for example, being an advisor). This was probed and observed in the deep dive farm visits, as this obviously has an impact on the process of adopting or not adopting DATSs. In particular, the farm visits showed that in some countries, such as Romania, distrust was politicised during the socialist years (until the 1989 Revolution). The farm visits also showed that in Spain, and even in Belgium and Netherlands there seems to be a distrust in the government. Ministries of Agriculture seem to be farmers' opponent rather than a trustworthy institute, evoking behaviour such as incorrectly filling in subsidy forms, with the goal to receive more funds than officially justified. In Finland, such behaviour seemed to be out of the question.

A factor related to culture that emerged from the farm visits was political history. For example, a history of land owning by farmers can impact their situation compared to state-owned land arrangements. Also, political history, in particular a former communist system, affects how farmers make decisions. For example, Romanian farmers still felt the need to demonstrate that they are part of Europe. As was mentioned by one of the farmers:

> *"There is this general feeling of distrust in each other, and to constantly be alert. This is what living in communist times does to a country. I feel it throughout the whole farmers' community."*

Also, growing up in a communist or post-communist society may have effects on the level of autonomy that farmers seek as well as the general level of trust in authorities and other people that they exhibit (link with trust). In post-communist societies land owning is only a recent phenomenon.

Finally, the farm visits also showed that geographical location can have an impact in several ways. First, the location of a farm determines the crop, the size, and climatological aspects; harsh climatological circumstances, such as extreme high or low temperatures or rainfall, may motivate a farmer to adopt DATSs in order to deal with these challenges. In addition, being near the border to an unstable region, such as Ukraine given the ongoing war with Russia, may discourage farmers to make high-risk investments in DATSs. Further, in some regions, labour is very scarce. For example, the Spanish farmer mentioned the lack of workers in their area as an incentive for adopting technology.

3.2.4. Interactions between the deep dives

In this paragraph, we reflect on the interactions found amongst the deep dive topics, as these logically became prevalent while the research progressed.

Gender and autonomy

Several of the deep dive interviews demonstrated the need for autonomy to interact with gender. Most female repondents mentioned their drive for education, intellectual stimulation, and personal development, whilst only few of the men did. Male respondents tended to describe more passively 'rolling into the business' because of heritage and it being the traditionally expected family role. It is possible that some of the female respondents felt compelled to emphasise their educations partially due to the context of being interviewed by female researchers. This possibility is merely conjecture, however, it would not be unreasonable to expect given the strong social pressures that surround female gender roles. Although male respondents did not, on the whole, display the same level reflection on their paths, dreams, sacrifices, and accomplishments, an explanation rooted in gender roles could also be proposed for this pattern in that it is less common, less socially acceptable, and less trained for men to openly engage in this type and depth of conversation than it is for women. That is certainly not to say, however, that pressures on men do not exist (e.g., to take over the family business, to provide for the family, and to perform the roles that are expected of them).

Another pattern at the interplay of gender and autonomy was detected in the lack of recognition women receive within the sector. As confirmed by the two female main operators of their farms, the need for autonomy is relevant (and often challenged) in the course of doing business (e.g., sales, stakeholder management, relations with their service providers). These female farmers reported that their accomplishments were not viewed in the same way as those of their male counterparts and that there was often an element of struggle in order to associate with others in the industry and have their skills, actions, and volition be recognised and respected.

Autonomy and culture

While there may be some cultural differences in desire for (i.e., stated importance placed upon) autonomy satisfaction, these differences do not appear to translate into autonomy need satisfaction being more or less predictive of well-being. In other words, regardless of one's level of desire for autonomy satisfaction, satisfaction still predicts well-being and frustration still predicts ill-being (Chen et al., 2015). In practice, this finding can serve as a reminder that autonomy satisfaction is always an important factor to probe and to aim to facilitate.

Furthermore, while some differences in autonomy valuation were observed (e.g., with respondents from Spain, the Netherlands, and Ireland seeming to be more vocal about the importance of autonomy), these

cultural differences were not consistent. This aligns with the notion that cultural differences are differences in group averages that can only say something when zoomed out; there is significant individual variation in all cultures and, as such, interactions with individuals cannot be used to draw conclusions about cultural differences. This means that knowing an individual's culture does not mean that you can predict their beliefs, or vice versa. As expected, a variety of positions about the extent to which one personally values autonomy were observed. Interestingly, similarities in the challenges that frustrate the respondents' autonomy (e.g., paperwork, government regulation) and in the behaviours that satisfy the respondents' autonomy (e.g., working hard, working for themselves, doing what they want in terms of crops and processes) were observed, perhaps pointing to a shared culture between farmers.

While the need for autonomy may be universal, the conversation around autonomy satisfaction may thus vary from culture to culture. For example, in one culture it may be easier to have a fruitful discussion about the importance of autonomy if there is a cultural norm that celebrates and encourages deriving fulfilment from autonomy. In another culture, by contrast, a conversation around autonomy may not be so easily understood or accepted. Instead, a conversation about autonomy might be more effective if it centres an individual's value-based goals (e.g., honouring one's values, achieving stability and freedom, enjoying a simple and balanced life) that would provide autonomy satisfaction, without necessarily emphasising the end effect of satisfied autonomy.

Culture and gender

Gender roles differ per country (Best & Williams, 2001) and therefore culture and gender are intertwined in this domain. Countries such as Finland and the Netherlands are known for their gender equality. This influences decision making but also other aspects, such as, for instance, more gender neutrality when it comes to successors of the farm. On the contrary, countries with a more traditional character, often linked to Hofstede's dimension of masculinity-femininity (1980, 2001) see men as head of the family (farm) and women as the main care provider. In more "masculine" countries (e.g., Romania) differences in approaches towards DATS and the adoption therefore are more distinct and profound, calling for an even more gendered approach to DATSs adoption.

NB: Given that the deep dive research in itself is a rather new approach in this domain of DATS adoption, and because of potential sensitivities related to the deep dive topics, the research team also reflected upon the research techniques applied for the deep dives. These reflections can be found in Appendix A.

3.3. Outcomes Surveys

3.3.1. Survey for DATS adopter farmers

All Test Case farmers that are deploying the DATS under assessment by the project, were approached to take part in a survey, regarding their DATS 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 repondents 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.

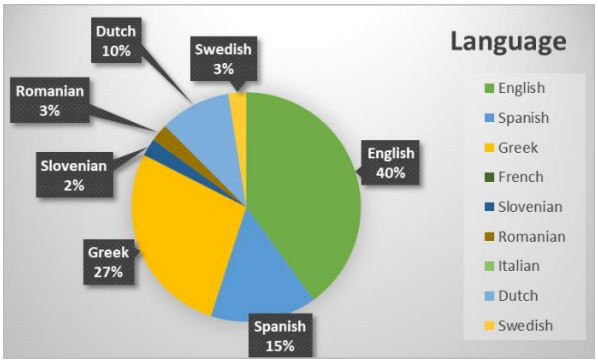


Figure 7: Preferred language

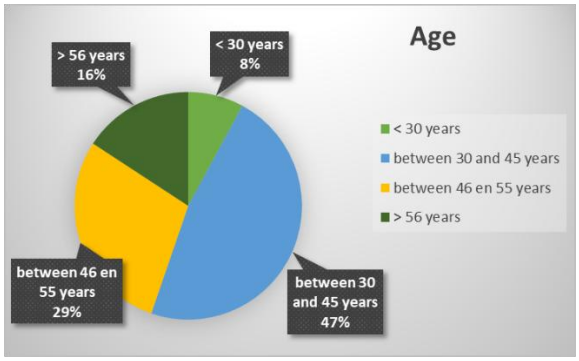


Figure 8: Age category

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 DATS-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).

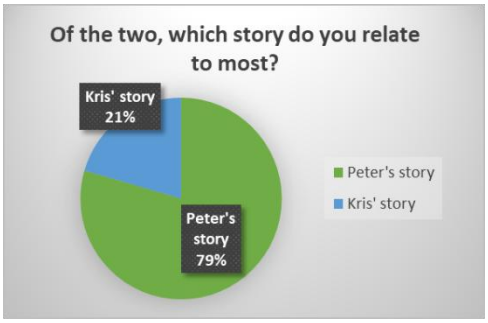


Figure 9: Most relatable farmer story

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 number of respondents is relatively small).

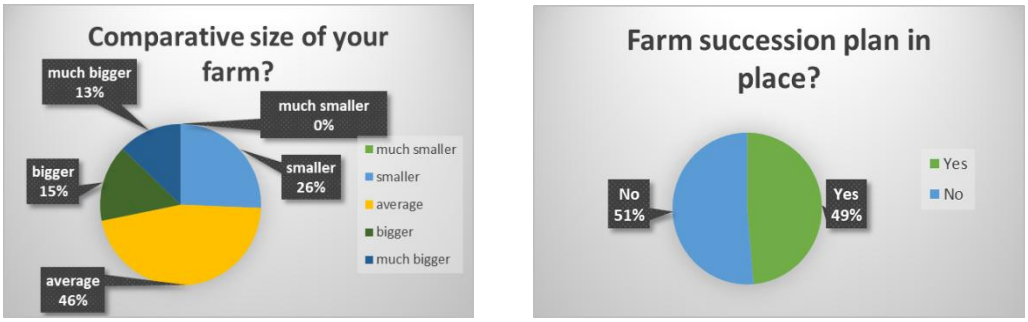


Figure 10: Farm size and succession

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.

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"

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."

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*"

Affinity with technology

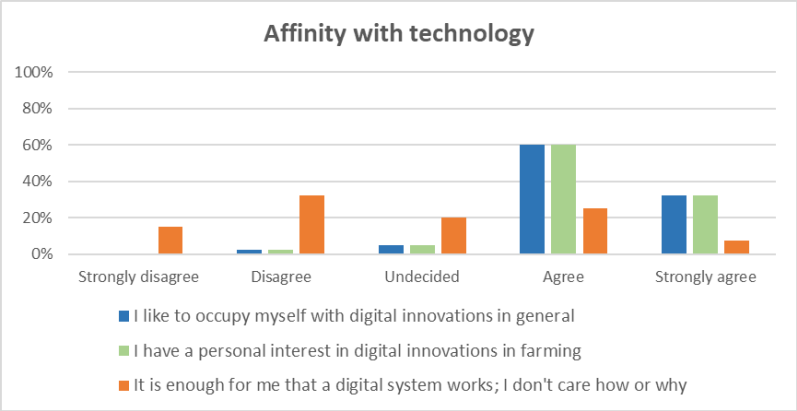


Figure 11: Technology affinity

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 DATS 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 DATS 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.

DATS investment and application

The biggest group invested in the DATS somehow, with 42% investing themselves and 10% together with others. Another substantial group of 38% does use the DATS, 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 DATS the most (84%). The way respondents interpreted their time working with DATS 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 DATS. It is possible that with more experience working with the DATS (and confidence that the DATS works well) a reduction in time in analysing and interpreting and making data-driven decisions is possible.

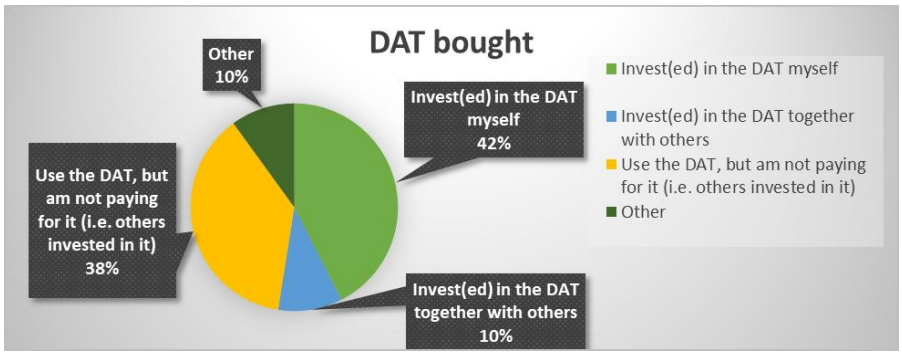


Figure 12: DATS financial investment

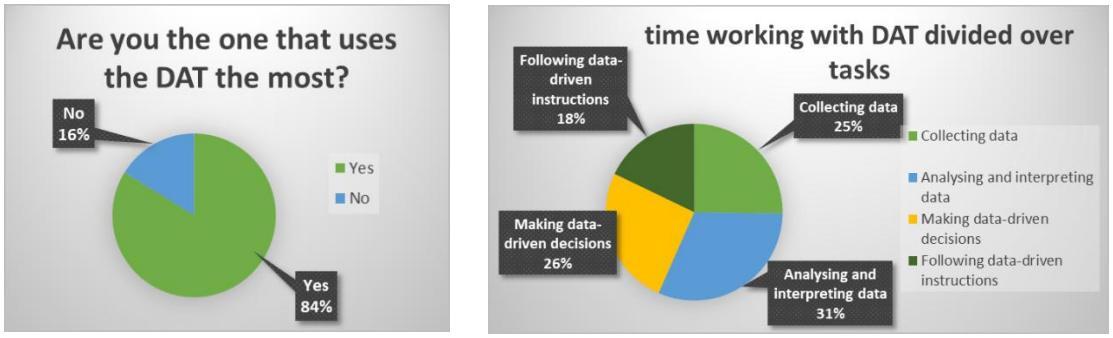


Figure 13: DATS use

Below, factors were prioritised by the respondents on how important they are in their consideration to invest in DATSs 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 agriculture technology solution (DATS), 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 DATS?			
RANKING*	*ALL*	*bought=1;2*	*bought=3;4*
Factors	**Average placescore**	**self bought/ invested with others**	**not self bought or invested**
Performance of the DATS (e.g., improving yield, reducing costs, ensuring certification)	2,0	1,8	2,2
Ease of use of the DATS (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 DATS	4,6	4,7	4,4
Trust in how the DATS works (e.g., how my data is secured, and that it is up-to-date)	4,4	4,5	4,1
How the DATS 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 DATS 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 DATS 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 DATS, 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 DATS 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 DATS to be able to determine this properly. However, it is indicated that costs may play a more important role in the future, too.

DATS opinions on benefits

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

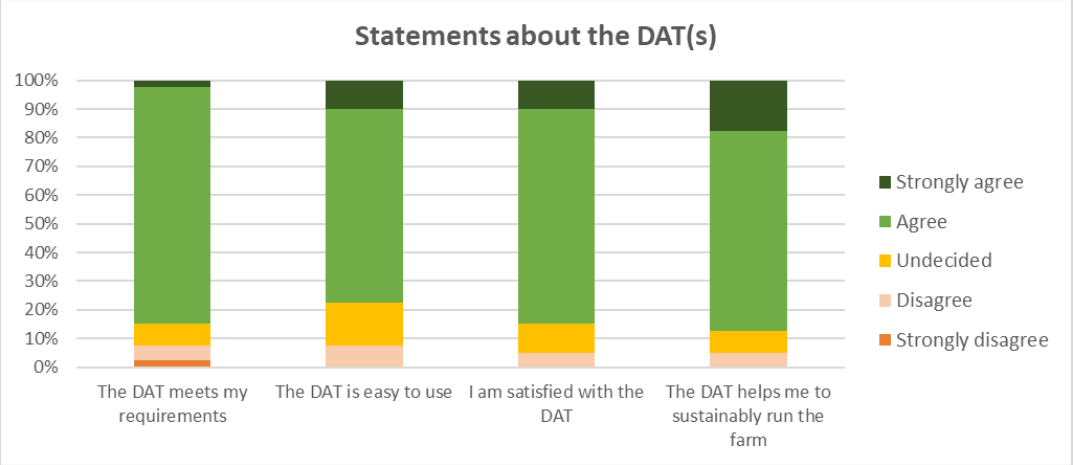


Figure 14: Statements about the DATS

Sustainability needs

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

"Data to reduce fertilizer, cereals, water, time and other resources. 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"

DATS impact

Next, they were asked what the biggest change was the farm went through after implementing the DATS. 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 freshness 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 DATS versus not deploying a DATS resulted in this range of answers:

"Increased speed in our logistics/production and increased trust from consumers with DATS"

"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 DATS adoption drivers and barriers, in order to prioritise functions and argumentations for further activities in QuantiFarm.

Interaction with the DATS

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

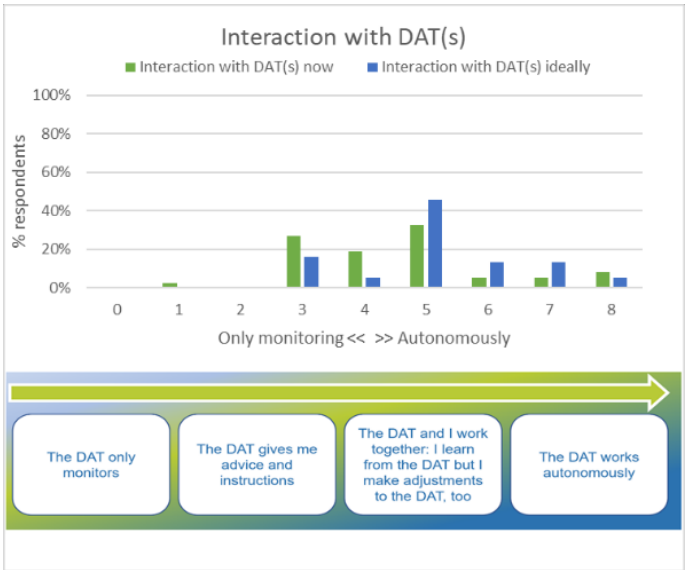


Figure 15: Level of autonomy of the DATS

The graph shows that most farmers place the DATS 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 DATS should ideally become more autonomous, and for instance attain more of a 'co-worker' status, but should not become totally autonomous.

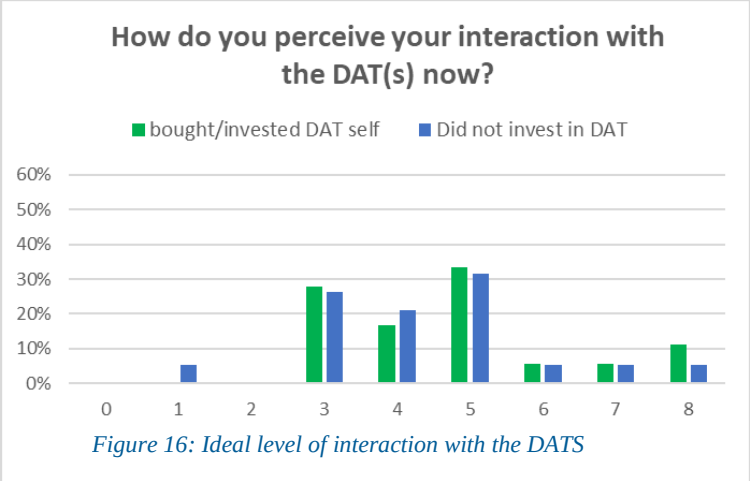


Figure 16: Ideal level of interaction with the DATS

The question on perceived DATS interaction was also compared between farmers who did and did not invest in the DATS 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).

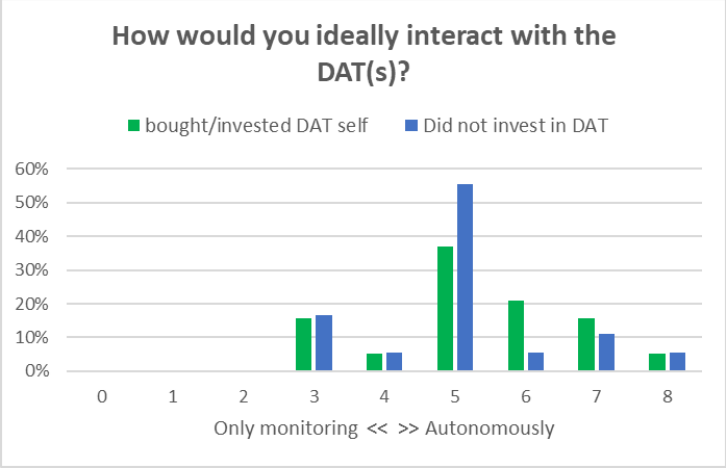


Figure 17: Perceived DATS interaction divided between investment

Below follow some quotes from respondents on the current and ideal DATS 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 every technology, I believe, that it is best when it is used with some human interaction, to at least check and control its operations. 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 [DATS] 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 [DATS] 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)".*

3.3.2. Survey for DATS non-adopter farmers

All Test Case farmers that are NOT deploying the DATS under assessment by the project, were approached to take part in a survey, regarding their reasons not to adopt the DATS (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.

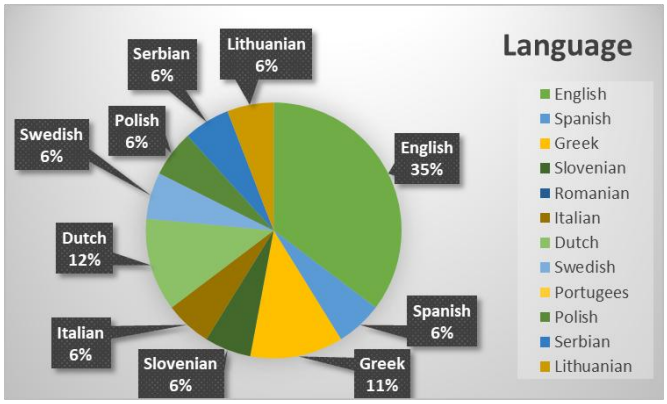


Figure 18: Preferred language

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

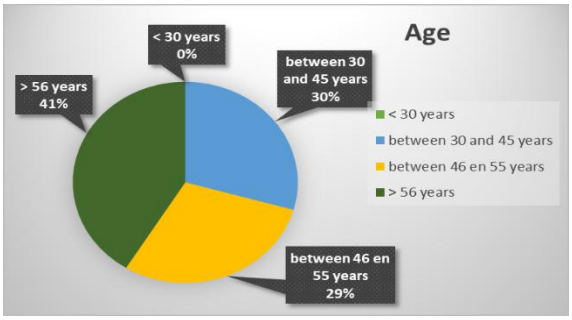


Figure 20: Age category

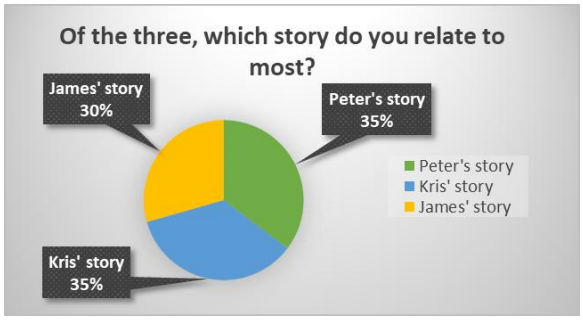
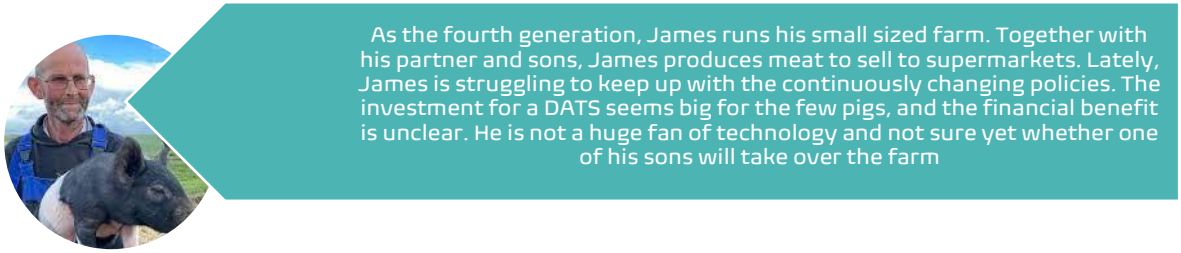


Figure 19: Most relatable farmer story

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

Farm size and succession

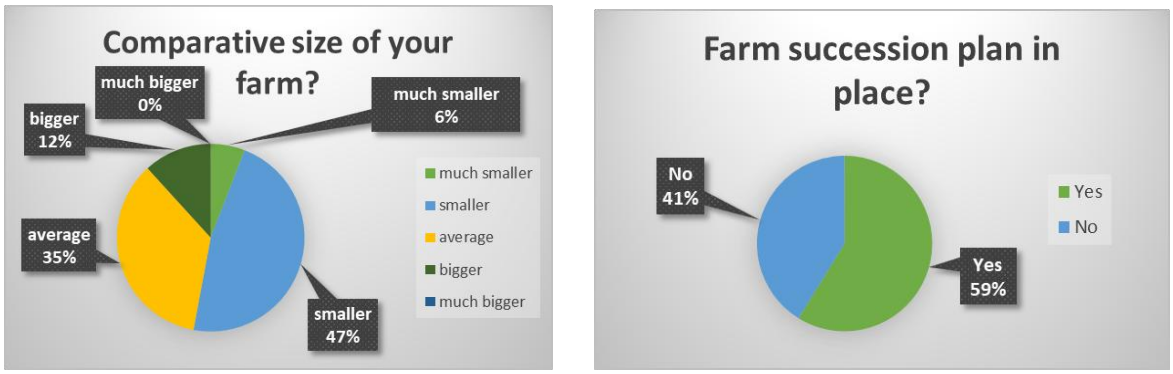


Figure 21: Farm size and succession

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:

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"

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*"

What are your main concerns for your farm?

Mentioned often: regulations, costs

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

"Bureaucracy 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.

Affinity with technology

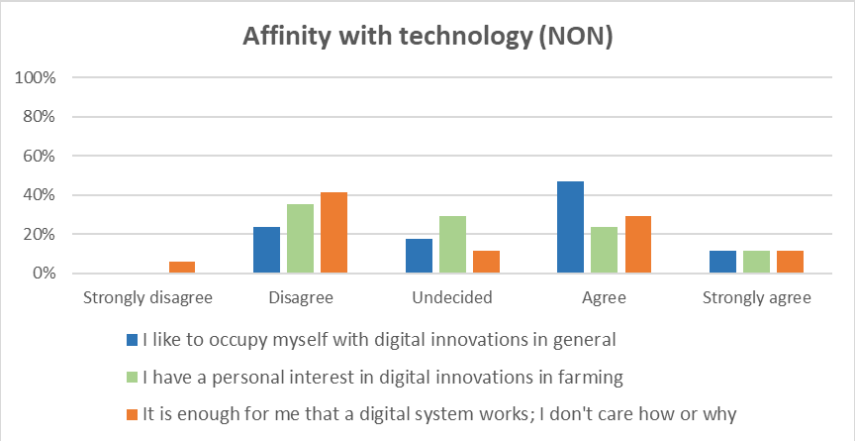


Figure 22: Technology affinity

This group adopters seems less interested in digital innovation compared to the DATS 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 agriculture technology solution (DATS), 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 DATS?	
RANKING*	*Non-adopters*
Factors	**Average placescore**
Performance of the DATS (e.g., improving yield, reducing costs, ensuring certification)	2,6
Ease of use of the DATS (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 DATS	5,3
Trust in how the DATS works (e.g., how my data is secured, and that it is up-to-date)	4,6
How the DATS 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 DATS" is rated as the most important factor to consider investing in DATSs, followed by "How the DATS 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 DATS fits with their existing practices.

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"

What would you need from a DATS 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 flux, 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:

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

Some representative answers:

"Best example is registering calves online"

"Things become manageable when we do deploy DATS"

"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"

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"

What factors do you find most important for not choosing DATS(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 DATS 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 DATS.

Interaction with the DATS

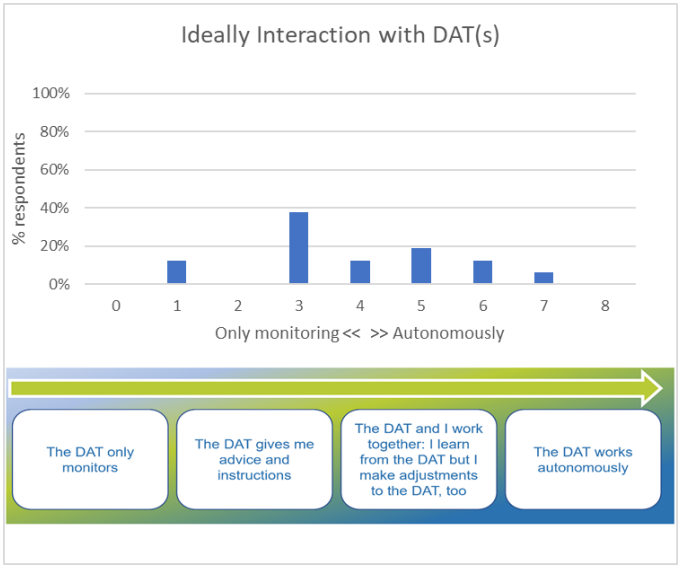


Figure 23: Ideal level of interaction with a potential DATS

Lastly, the respondents were then asked to rate, if they would deploy a DATS, what their ideal level of interaction would be, on a slider scale (1 being a basic level of operation i.e. the DATS only monitors; and 8 being the highest level of a fully autonomously operating DATS). 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.

3.4. 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 DATSs. 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	Arable	Livestock	Horticulture	Fruit farming
Type				
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[8].

3.4.1. 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 DATS 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:

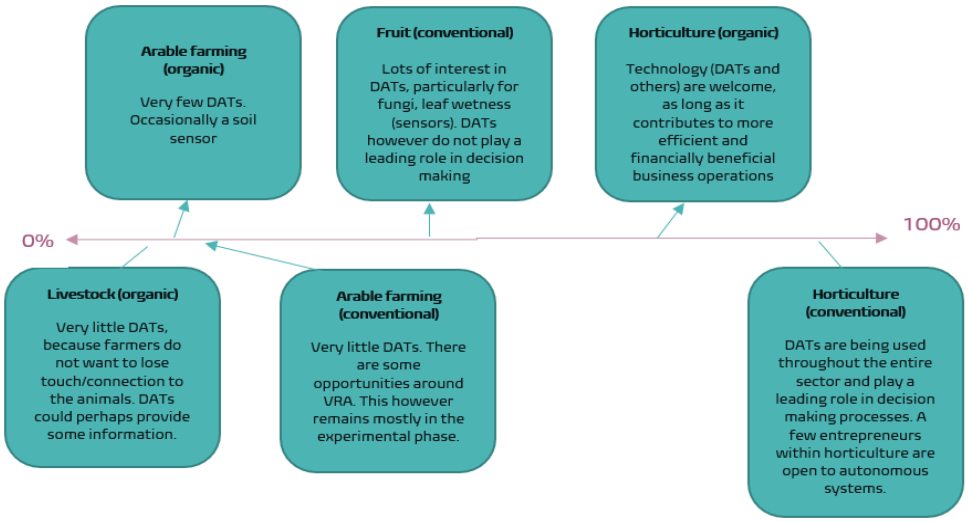


Figure 24 Adoption degrees per sector

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

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

- DATS adoption is a gradual process, not a binary matter of either 'yes' or a 'no';
- Not only the presence of a DATS 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 DATSs to decrease this reliance;
- And there seems to be less DATS adoption in organic farms in comparison to non-organic (conventional) farms. Probably because organic farmers are less tempted to focus on profit.

3.4.2. 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 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 DATSs, but without a compromise on their autonomy and (image of) being an ecologically driven farmer.

Figure 25 Non-adopter archetypes

4. The integrated DATS adoption framework

As we have seen, to truly understand DATSs adoption, it is essential to capture farmers' experiences of DATSs adoption throughout the process of decision-making, from first thought of potential procurement, up and until full usage of the technology.

All the research conducted by WP1 together produced such a breadth of knowledge around DATS adoption and revealed such a range of influences that it seemed the most comprehensible way to unite all of them was via a new integrated framework. The novelty of this particular QuantiFarm framework stems from its incorporation of different perspectives and literature on behaviour determinants, and from its simultaneous framing of DATSs adoption as a journey (rather than a singular moment, a simple binary decision) that begins with an initial encounter and subsequent consideration and ends with habitual use and total integration of the DATS.

4.1. Framework evolution

The preliminary framework illustration

The preliminary 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 (see figure 25 below).

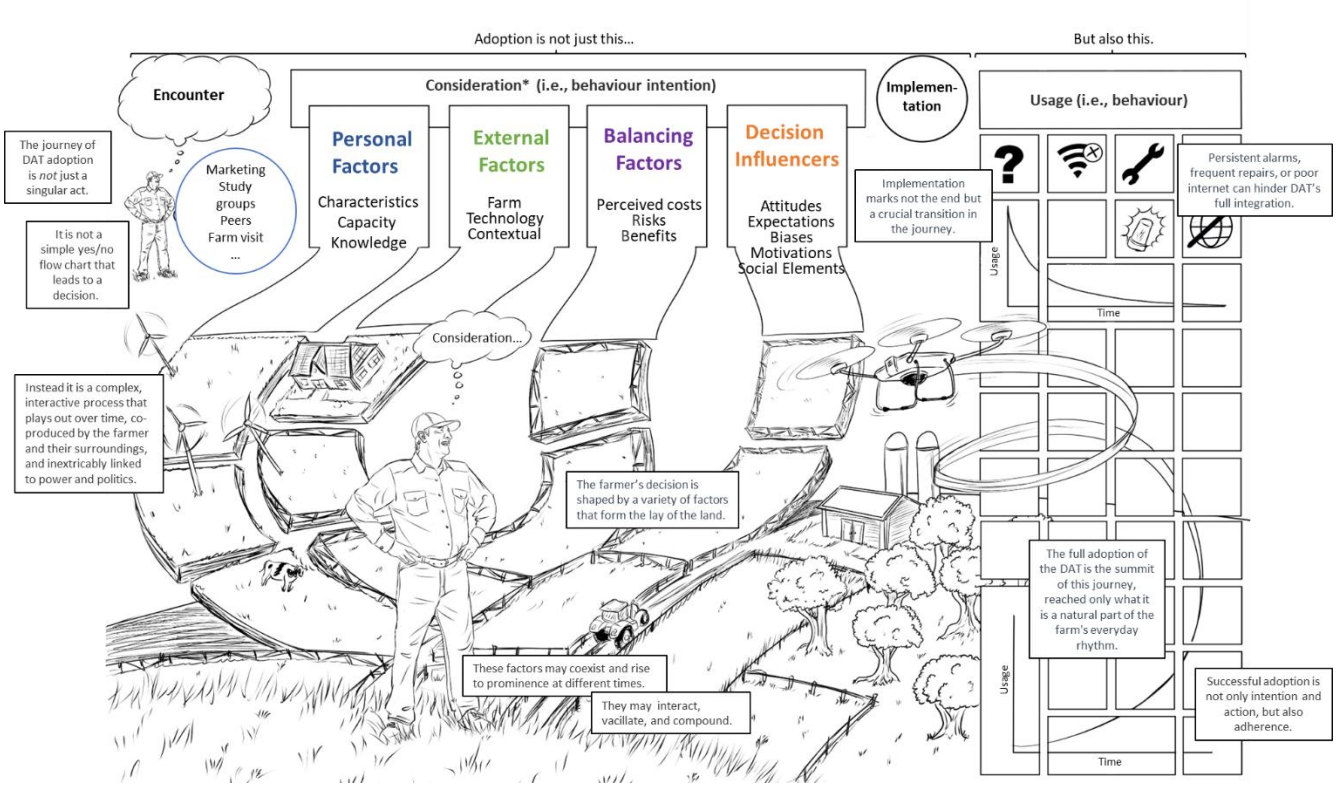


Figure 26 Preliminary QuantiFarm integrated DATS adoption framework - overview

The framework tells the story of how the adoption journey starts with an encounter with a DATS, either by chance, through marketing campaigns, from peers, via 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 DATS;
- Balancing factors, which are the factors with which a farmer weighs his or her decisions, such as perceived risks of implementing (or not implementing) a DATS, expected maintenance costs, and expected returns;
- Decision influencers, which 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 their capability of working with technology; life goals; and, crucially, the social influence of the people around the farmer.

After this process of consideration, which often involves going back and forth between factors, follows an implementation decision, which may be the decision: not to implement anything (for now); to run a trial; to do a full-blown roll-out; or variations in between, such as trialling one part of the DATS, followed by another, etc. Lastly, and critically, is the usage phase, in which many factors still influence how well a DATS is truly adopted and to what extent it is utilized and 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 DATS usage in WP1. Lastly, dealbreakers to be aware of, that can also cause for a DATS to be no longer deployed, are items such as the DATS leading to an overload of work, or having overly intrusive of alerts.

The revised integrated DATS adoptions framework

After the deep dives and continued data collections, the framework was revised to achieve its final form (below, figure 26). The behavioural determinants have been expanded and tweaked to most accurately and concisely represent the influences on farmers' decision-making regarding DATS adoption.

One notable addition is of the "culture" layer at the bottom of the framework. As revealed in the deep dives, culture is a highly significant theme that exerts its influence in a multitude of complex ways. Culture filters how we perceive the world, how we think, and how we interact with others. As such, it was more accurate to include culture as a layer rather than try to artificially list it as a single factor within the integrated framework. Following are a few examples of how Hofstede's cultural dimensions could interact with various framework factors to exemplify the myriad ways in which culture plays a role in DATS adoption and why it is best understood as a layer. In a collectivist culture, a farmer may be more likely to encounter a DATS from a peer or associations and may be more heavily influenced by social norms and pressure, whereas in an individualistic society, a farmer may weight their individual and recreational goals more heavily. Compared to a farmer from a short-term outlook culture, a farmer from a long-term outlook culture may be more interested in a growth-oriented DATS may be less deterred by a steep learning curve (i.e., effort expectancy), and may more readily consider climate change in their moral obligations. A farmer from an indulgent culture may be more motivated by hedonic motivations than a farmer from restrained culture. A farmer in a masculine culture may take a more assertive approach to joint decision-making than someone in a more feminine culture, and may be more likely to prioritise goals and benefits related to finance and status than to well-being and balance.

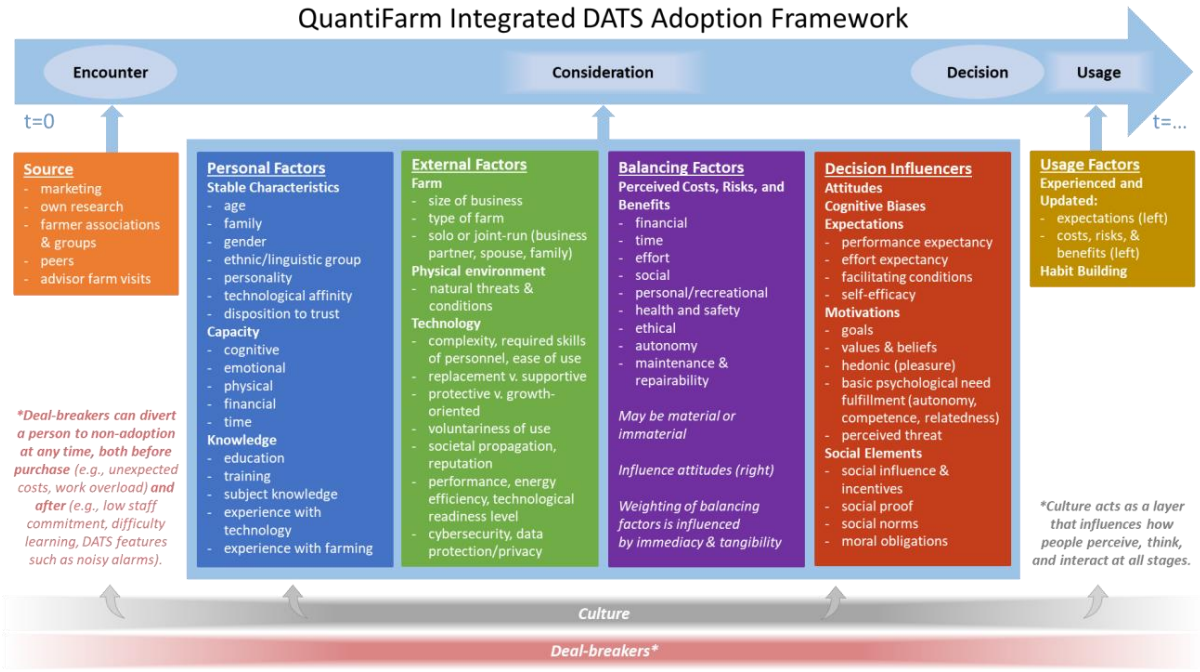


Figure 27 QuantiFarm integrated DATS adoption framework - with determinants

Explanations and/or examples of each factor can be found below in Section 4.1.

The integrated framework is intended to be applied in several ways. Firstly, it serves as a comprehensive overview of behavioural determinants which should be used as a reference to ensure that consequent guidelines are more relevant and complete. Secondly, it is a means to incorporate meaningful and relevant indicators in the tools and instruments that are being developed by other QuantiFarm Work Packages, such as the QuantiFarm Assessment Framework and the Recommendation Tool. Thirdly, it supports the dialogue with stakeholders on what elements are most relevant to consider in regard to DATS uptake and usage.

4.2. Integrated framework factors: explanations and examples

The following pages provide a brief explanation or an example of how each factor from the Integrated Framework might influence DATS adoption for a hypothetical farmer. The examples are not true of everybody. They serve merely to illustrate one way that a factor could express to influence decision-making. The examples come from observations made and statements heard during the TC visits.

Source

- Explanation: Farmers first hear of DATSs through a range of mediums. These encounters include hearing about the DATS from a neighbour, finding it online when researching innovative methods, learning about it when attending farmer association meetings, being visited by an advisor or supplier, and being exposed through marketing. Some encounters are more passive on the farmer's part (e.g., hearing from a neighbour and being the target of marketing), whereas others are more active (e.g., participation in association outings and directed research).

Personal factors

Stable characteristics

Age:

- Explanation: Age can be related to many factors, such as affinity for technology and plans for farm succession.
- Example: An older farmer may be reluctant to digitalisation if they have less familiarity with technology, more intuitive expertise upon which they can rely, and an overall more traditional approach to farming. Alternatively, aging may be a reason that a farmer becomes more open to adopt a DATS, for instance because it can reduce the burden of physical or mental labour.
- Example: A middle-aged farmer makes an explicit effort to involve DATSs because their child is considering taking over the family farm and the farmer wants the business to be sustainable and appealing to their child.

Gender:

- Explanation: Gender is related to other factors, such as risk-taking; in general, men tend to take more financial risks than women, whereas women tend to take more social risks than men. Gender is also important because female farmers face more barriers and different barriers than male farmers do, across countries.
- Example: A son is more readily assumed to be a successor than a daughter, and as such by default is socialized more into the farming business (e.g., by being taught to drive a tractor as a child).
- Example: A female farmer is less integrated in male-dominated farming associations and needs to search for information elsewhere.
- Example: A female farmer feels that she has less room for error due to a spotlight being on her because of her gender and different expectations around experimentation, tinkering, and risk-taking.

Ethnic group:

- Explanation: A farmer's ethnicity may be relevant in terms of circumstances such as whether local associations tend to group according to ethnic lines, whether there are historical tensions in terms of land ownership or stewardship, whether a farmer is of the ethnic/linguistic majority or minority, whether a farmer's farm has generations of heritage, whether a farmer is a newcomer with practices and crops that are less common in the area, etc.

Personality:

- Explanation: Personality is too nuanced to draw clear examples. However, as an advisor, it makes sense to know your farmer. Keeping these types of personality traits in mind, in conjunction with other factors, will enhance the relationship between advisor and farmer.
- Example: Extroversion. Are they extroverted and willing to talk to other farmers and have regular visits? Or, are they more comfortable doing their own online searches?
- Example: Openness to Experience. Are they open to and curious about new things or do they prefer familiarity and routine?
- Example: Stubbornness. Depending on what the stubbornness pertains to (e.g., being in charge, being independent, being environmentally friendly, maintaining tradition), the effects on deciding whether or not to use DATSs differ.
- Example: Flexibility. In general, farmers demonstrate flexibility regularly in the sense that they all experience limitations and obstructions from policy and bureaucracy, and must also continually adapt to natural and market conditions. That said, some do so much more gladly and effortlessly than others.

Technological affinity:

- Explanation: A person's technological affinity refers to their general relationship with technology and their tendency to either interact with it or avoid it.
- Example: A farmer enjoys playing with technology that is new to them, feels fairly competent with technology overall, and has a generally positive attitude towards technology, so they approach it more than someone with a more negative relationship with technology who might have feelings of intimidation, mistrust, stress, or boredom.

Disposition to trust:

- Explanation: People have different dispositions to trust. Some people are more likely to trust their fellow human beings, technology, and/or institutions, such as the government, than other people are. When building relationships with farmers, advisors should be aware that farmers may want to *build trust in different ways* (e.g., by demonstrating a reliable track record of task performance vs. by building a personal relationship). Advisors should also be aware that farmers may have different levels of trust (positive expectations), mistrust (cautious uncertainty), and distrust (active negative expectations) in different actors and objects, such as government, strangers, advisors, suppliers, and technology (in terms of data security, privacy, reliability, etc.).
- Example: Less trusting farmers typically have more hesitancy when adopting a DATS.

Capacity

- Explanation: To implement a new DATS, a farmer first needs the time and space to research and think about the decision. They must also foresee having the time and capacity after purchase to learn to use the DATS, train staff, and endure the challenges and adjustment period that come with changing protocol. In addition to time and cognitive capacity, financial and emotional capacity are also important. They would also need the physical capacity to use the DATS. Alternatively, a farmer may be motivated to adopt a DATS if it helps them with a task that is currently physically challenging.
- Example: A farmer who is busy with four young children may not have the capacity to explore new ways of working even though it may improve his efficiency once implemented.

Knowledge

- Explanation: Subject knowledge can come from a range of sources, such as hands-on experience, practical training, formal education, familiarity from general proximity, etc.
- Example: A farmer who has formal education and training but who lacks hands-on experience with a certain crop in a new region may turn to technology to supplement their perceived shortcomings and gain data insights tailored to the specific environment.
- Example: A farmer who has extensive farming experience with farming may feel secure enough in their expertise and in their ability to have a feel for their crops and for the conditions that additional data from technology may not be as appealing.

External factors

Farm

- Explanation: The farmer will certainly consider the characteristics of their farm (e.g., size, crop, ownership structure, organic or not) when considering the suitability of a DATS.
- Example: A corporate-owned farm has a bigger budget and more financial float than a neighbouring small family-owned farm.
- Example: A certain DATS is differentially suitable (and worthy of investment) to a farm with diverse crops than to a farm with a single crop.

Physical environment

- Explanation: Because of (a lack of) natural resources, farmers need more or fewer DATSs to assist them in bringing in the crops. These conditions might include soil salinity, heat for crops and animals, drought, pests, shifting harvest season, etc.
- Example: A farmer experiencing increasing drought conditions sees increasing appeal in water-saving DATSs.
- Example: A farmer in a region where a certain pest has not been eradicated but EU-wide policy bans a pertinent pesticide sees early detection DATSs as more appealing.

Technology

- Explanation: The DATS itself is a critical component. Characteristics of the technology determine its relevance to the user and to their farm. All these factors should be considered. Whether or not a farmer chooses to adopt a DATS is influenced by their *perception* of these DATS features (e.g., it's complexity), but whether or not a farmer integrates the DATS into habitual usage is influenced by their *experience* of these DATS features.
- Complexity, required skills of personnel, ease of use
    - Explanation: A more complex DATS costs more time and effort to implement, especially if it will be used by workers.
- Replacement vs. supportive
    - explanation: Technologies range in terms of whether they help the human perform the task (support) or perform the task for the human (replacement). People's perception of a DATS' position on the support-replacement spectrum influences their attitude and openness towards the technology.
    - Example: A farmer who identifies strongly as a farmer and with their work may find a DATS less appealing if it replaces them in doing that task.
    - Example: A replacement DATS might be very appealing if it replaces a back-breaking and repetitive task done by workers who can instead be moved to other tasks.
    - Example: A farmer who is keen to hone their skills and increase their knowledge may be very attracted to a supportive DATS that they can learn from and use to validate their intuitions.
- Protective vs. growth-oriented
    - Explanation: Does the DATS protect against losses and uncertainties, or does it offer potential growth and expansion?
    - Example: A farmer more worried about the effects of climate change may see the appeal of a protective DATS.
    - Example: A growth-oriented DATS may be more appealing to a farmer with more financial resources and entrepreneurial ambitions than a farmer who is uncertain about the future of their farm's succession and may therefore be more focused on maintaining what already exists.
- Voluntariness of use
    - Explanation: Is the DATS required for compliance with policy or is use entirely voluntary? If a new standard has been set, the DATS may be one (though not the only) way to meet the requirement.
- Reputation, societal propagation
    - Explanation: Does the DATS have a well-established reputation and is it used widely, or is it relatively unknown?
    - Example: It may take a more risk tolerant farmer or one who is confident in their hard research skills (instead of relying on anecdotal evidence) to be comfortable investing in a DATS that is less widely used.

- Performance, technological readiness level, energy efficiency
    - Explanation: Technological Readiness Level is a 9-point scale used to rank the maturity of a technology from concept through to prototype and, finally, to proven usage.
    - Example: A farmer with lower technological affinity or lower risk taking may be less willing to "experiment" with a DATS that is earlier in development and whose performance has not been as concretely proven.
    - Example: A farmer in a region with less reliable energy may be more reluctant to invest in a DATS with high energy consumption or which could cause harm to the crops in the case of a disruption.
- Cybersecurity, data protection/privacy
    - Explanation: What data does the DATS collect, where are they stored, and who has access to them? Some people are more concerned with security and privacy than others.
    - Example: A farmer who is more concerned with data privacy and security may be more reluctant to a DATS that collects photographs of his farm and crops.

Balancing Factors

- Explanation: "Balancing factors" refers to the pros and cons that people weigh. Although these "pros and cons" are often considered a more intentional and objective method of reasoning, the weight that people attribute to different balancing factors is often emotionally driven. The more tangible and the more immediate a factor is to a person, the more weight they give to that factor. "Perceived" precedes all three categories because, in a person's decision making, it is not the true costs, risks, and benefits that matter as much as those that they perceive. These factors can be material or immaterial.
    - Costs are cons that will occur.
    - Risks are cons that may occur. People have different levels of risk aversion/tolerance. Moreover, an individual can have different levels of risk tolerance towards different types of risks. *Note: There are also risks associated with not adopting a DATS (e.g., financial: of not updating; social: of rejecting the ideas and wishes of those around you).*
    - Benefits are pros that will or are expected occur.
- Financial
    - Cost: the price of the DATS.
    - Risk: making an investment that doesn't pay off financially.
    - Benefit: futureproofing, added revenue, subsidies, and profitability.
- Time
    - Cost: the DATS takes time to research and implement.
    - Risk: the DATS takes longer to learn to use than anticipated.
    - Benefit: the DATS increases efficiency and creates more free time or more flexibility to be away from the farm.
- Effort
    - Cost: the DATS costs effort to research and implement, especially if it performs a new capability instead of replacing an existing one on the farm.
    - Benefit: once the DATS is implemented, less effort is required.
- Social
    - Risk: of upsetting relationships, e.g., with partners, family, other farmers, workers. This could occur, for example, if the equipment creates unwanted noise for neighbours, upsets family by altering the traditions of a family farm, or disrupts family life by taking up time and money.
    - Benefit: happier workers
- Personal/Recreational
    - Cost: decreasing time enjoyed working hands-on with the crop.

    - Benefit: enjoyment of the DATS' aesthetic, enjoyment from exploring new and innovative method (epistemic value), knowledge that farm is more futureproof, sense of mastery or autonomy, fulfilment of basic psychological needs.
- Health and safety
    - Risk:
        - Of adopting: accidents, stress associated with investment and learning curve.
        - Of not adopting: sun exposure, chemical exposure, old equipment use.
    - Benefit: health benefits don't only refer to reduced sun exposure and back-breaking work. They also include reduced stress, and more time spent with family.
- Ethical
    - Cost: a farmer may resent turning to new methods that involve high-tech solutions from larger corporations or diverting from traditional ways of farming that were used by previous generations.
    - Benefit: knowledge that you are decreasing your impact on the environment.
- Autonomy
    - Cost: the DATS will automate some factors so that the farmer isn't as involved in every decision.
    - Risk: the DATS may not provide all the raw data that the farmer would like to tinker with themselves.
- Maintenance and repair
    - Cost: the DATS will eventually incur costs related to maintenance and repair.
    - Risk: repairs may be greater or more frequent than anticipated, or even permanent.

Decision Influencers

- Explanation: This category of factors relates more to psychological processes and constructs. Decision-making, like all cognition, is subject to the many filters and falters of the human brain.

Attitudes

- Is the farmer's general evaluation of and feeling toward the DATS positive or negative? Attitudes have emotional, behavioural, and cognitive components. They are influenced by balancing factors (left) as well as decision factors (below). Attitudes influence behavioural intention.

Cognitive Biases

- Explanation: Human thinking (including decision-making) occurs through cognitive processes that are built on recognising patterns and making short cuts. As such, thinking is inherently biased and prone to some degree of error. Cognition is also heavily influenced by emotion. Awareness of biases can help mitigate their impact.
- Example: framing effects describe people's tendency to prefer messages that are framed positively (i.e., in terms of gains) than messages that are framed negatively (i.e., in terms of losses). For example, a farmer would likely be more open to a DATS framed as reducing pests (a positive outcome) than to a DATS that warns of an increase in pests without the DATS (a negative outcome).
- Example: people tend to overvalue and over-rely on emotional information when making decisions. Additionally, pre-existing emotional associations (positive or negative) can bias people towards or against things. Emotions are not a bias, per se, but they do exert powerful, complex, and diffuse influence on decision-making and are therefore worthy of note.

Expectations

- Performance expectancy
    - Explanation: the amount of improvement in performance the farmer expects to gain through using the DATS. Similar to another construct in the literature: outcome efficacy (a belief about the likelihood of the behavior leading to a specific outcome). Higher performance expectancy is related to higher behaviour intention.

- Effort expectancy
    - Explanation: The ease of use or effort that the farmer expects the DATS will require. Similar to another construct in the literature: perceived behavioural control.
- Facilitating conditions
    - Explanation: the infrastructure to support using the DATS
    - Example: The greenhouse having space to house the DATS, the DATS provider being available for troubleshooting and training, and the workers speaking the language of the DATS interface.
- Self-efficacy
    - Explanation: Self-efficacy refers to how confident a person feels that they have the skills and abilities necessary to succeed in a certain environment or with a certain task.
    - Example: A farmer who has high self-efficacy is likely to have a more positive attitude towards the challenge of integrating a new DATS into their process.

Motivations

- Goals
    - Explanation: What is the farmer's view of the future and what do they want to achieve? Consider their goals and outlooks regarding personal development, farm expansion, work-life balance, sustainability, heritage, retirement, (family) succession, etc.
- Values & beliefs
    - Example: A farmer who believes strongly in the value of hard work may be less motivated to adopt a replacement DATS, if the task is one that they value highly.
    - Example: A farmer who values time with their family may be more motivated to adopt a DATS that allows them to do some remote monitoring.
    - Example: A farmer who holds traditionalist beliefs may be resistant to change in general but may be more willing to accept a DATS that supports their traditional ways than one that disrupts and innovates.
- Hedonic motivations (desires & preferences)
    - Explanation: the enjoyment, fun, or pleasure that the farmer expects to get out of using (or not using) the DATS
    - Example: A farmer who enjoys working in the fields with their crops will be less likely to adopt a DATS than a farmer who enjoys tinkering with new technology.
- Fulfillment of basic psychological needs
    - Explanation: Psychological research has established a few basic psychological needs that are universal across cultures: the needs for autonomy, competence, and relatedness. When these needs are met, wellbeing and motivation increases.
    - Example: A farmer who gets a sense of satisfaction working with her hands and whose values prioritize feeding her local community may be less interested in a DATS that reduces her time in the field and facilitates broader distribution. Her original way of working may better satisfy her need for autonomy.
    - Example: A farmer who places heavy value on their sense of independence may be more resistant to a DATS that will help with compliance with new stringent policies, because the policies (and the DATS) make the farmer feel that they are not in charge of their decisions and actions.
    - Example: A farmer whose work is challenging them at the right level would find it rewarding and motivating and would have more confidence to take on a new challenge (such as learning a new DATS). The need for competence speaks to life in general and need satisfaction can come from many sources.
- Perceived threat
    - Explanation: Is the farmer motivated to consider a DATS because of a specific problem/threat, or are they simply open to general improvement?

- Example: A family farmer feeling the weight of the rising cost of living and a challenging market decides to make more prudent financial choices for the next few years.
- Example: A farmer acutely aware of changing patterns in heat waves and drought conditions decides to put more time in to researching protective solutions.

Social Elements

- Social influence & incentives:
  - Explanation: As social creatures, people are constantly influenced by those around them. Social influence can be exerted intentionally or unintentionally, as well as felt to differing degrees of intensity.
  - Example: A farmer feels pressure from members of their association to update and digitalize.
  - Example: A farmer is often visited by neighbours who stop by and end up discussing the farm.
  - Example: A farmer feels pressure to invest in an early detection DATS, not only to prevent pests on their own farm, but also to avoid risking spread with neighbouring farms.
- Social proof:
  - Explanation: The tendency of people to look at the behaviour of those around them to inform their own behaviour (often following what they see).
  - Example: A farmer who is not an early adopter of technology waits to see how a DATS works out for his neighbours before deciding to adopt.
- Social norms:
  - Explanations: Whether they are explicitly or implicitly stated, social norms are a strong source of behavioural influence.
  - Example: A farmer's wife chooses a job that is less demanding in the summer months so that she can help more on the farm, following a typical local norm.
  - Example: A farmer feels compelled to avoid noisy work on Sunday due to local religious and cultural norms.
- Moral obligations:
  - Explanation: People have internal beliefs about what is right and what they are comfortable doing.
  - Example: A farmer whose faith tells them that it is important to feed their community may be more open to DATS that facilitate that goal.
  - Example: A farmer who is concerned about climate change (i.e., problem perception, perceived threat) and believes it is their duty to try to protect the environment for future generations is more likely to adopt a DATS that supports sustainability.

Usage Factors

- Explanation: Usage factors describe how the DATS is experienced in practice, and help explain how quickly and how well a DATS becomes integrated into habitual usage. Not all DATSs that are purchased go on to be permanent fixtures. Focusing on optimizing these factors is especially important when the DATS is being used on a trial basis or as part of a pilot, to maximize the likelihood of adoption.
- Experienced and updated
  - Expectations (see left)
    - Explanation: In practice, is the DATS smooth and easy to use or is it clunky and challenging?
  - Costs, Risks, and Benefits
    - Explanation: What were the actual costs and benefits experienced? Which risks manifested? What are the perceived costs, risks, and benefits going forward?

        - Example: Were there unexpected fees? Did the change create frustration or excitement amongst workers? How much free time has the farmer had to dedicate to the DATS, and how long do they see this continuing?
- Habit Building
    - Explanation: To be completely integrated into protocol, DATS usage should be habitual. Habits are not always easily changed though. The degree to which habit change can occur relates to factors such as motivation, ease of use, and the DATS itself.
    - Example: If the DATS provides new information to the farmer, but doesn't replace their old methods, habitual usage may come more slowly than a DATS that replaces an old method and thus is automatically used every day.

Dealbreakers

- Explanation: As illustrated in the Advisor part in the Guidelines, where a flowchart is shared to support a farmer's DATS adoption journey flowchart, dealbreakers can occur at any time and divert a farmer from their path to adoption back to non-adoption. This can be temporary (if the farmer later chooses to reconsider) or permanent.
    - Example: A farmer is overloaded and overwhelmed. In other words, they do not have capacity. This would likely be a temporary dealbreaker, until such time as they do have the capacity to resume consideration.
    - Example: A farmer has difficulty learning how to use the DATS. This is likely to more seriously impact the chances of adoption during a trial phase with the DATS than after significant investment.
    - Example: Very basic DATS features, such as noisy alarms, can be the difference between a farmer using the DATS or not.
    - Example: Price, customer service, and personal matters (e.g., life events/choices) can also be dealbreakers.

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 DATS uptake, this empathy is crucial. Therefore, to illustrate how an individual farmer's decision-making process may unfold, driven by this myriads 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 DATS (or not). The stories exemplify what a hypothetical farmer's "DATS 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 have formed the basis of interactions with stakeholders on the implications of the behavioural findings in this project.

The farmer profiles in the stories were informed by all research outcomes of the first phase of the project, and the consequent framework in Chapter 4, in order to be realistic and representative. Because the topics of gender, autonomy and culture were already distinguished, subtle references to these are made in the stories, too. An overview of what the storyboards look like is presented in Appendix F. The storyboards themselves are part of the Guidelines document[9].

The colour codes match the colour codes of the determinants in the DATS 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 DATSs; 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.

[9] They can also be found here: The power of storytelling: QuantiFarm Storyboards by TNO – QuantiFarm

A while later, his work-life balance turns out different than it used to be for his father. The son sees the DATS 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 DATSs 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 E.

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 DATS 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 DATS: 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 DATS 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 DATS 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 DATS 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 DATS 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 DATS.

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 DATSs (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 DATS 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 DATS, 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 DATS 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 DATS 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 DATS 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 DATS 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. Guidelines

Beyond sharing the results of our data collection and analyses, the aim of WP1 is to engage and empower key stakeholder groups to work with these results. Guidelines therefore serve to, in an informed way, suggest and implement behavioural interventions that may help the process towards DATSs adoption. Furthermore, guidelines ensure that stakeholders have a consistent understanding of the findings, which facilitates transparent communication, and reduces the risk of misinterpretation or misuse of the found data. (Of course, guidelines are recommendations and not strict rules; they can be adjusted if the situation so demands). The guidelines created by WP1 are delivered in a separate document called **QuantiFarm_WP1 Guidelines DATS adoption** and are available via the QuantiFarm website.

Our guidelines have been organised according to the main stakeholder groups intended to apply the insights from the QuantiFarm behavioural analysis: farmer advisors; DATSs developers; and policy makers. A fourth group we address in the guidelines are the farmers themselves; a question the WP1 team has regularly heard from the farmers was whether the insights from our research could be shared with them. Given the heavy reliance for our work on what we have heard from the farmers, this request is nothing more than justified. Also, it is relevant for the farmers themselves to be on the same knowledge level as those concerned with their innovation processes. Per stakeholder group, the guidelines have been separated in 2 parts: main insights (from our analyses); and main implications (i.e. suggestions for behavioural interventions). Logically the insights are comparable per stakeholder, yet the implications differ.

A last key element that is worth mentioning is the tool ("mnemonic") that has been created by the WP1 team to facilitate dialogues about DATSs adoption, as the results all together could be rather daunting. This tool is introduced in the "Advisor" part of the guidelines, and called: WE THRIVE, as we state:

"Using this Quantifarm approach, WE (all, including the environment) THRIVE!"

WE THRIVE consists of the following elements:

Before your visit		
W	World	Go into the farmer's world – the farm, the greenhouse, the kitchen table. Meet the farmer, and important people around the farmer, in their space to understand the farmer's reality.
E	Earnest	When you interact, be earnest, sincere, warm, curious, and non-judgmental in order to establish a safe and trusting relationship.
During your visit		
T	Technological affinity	Savviness/Training/Tinkering: How tech-forward is the farmer? What is his/her formal training, knowledge, and education? Does the farmer enjoy learning, problem-solving, and experimenting?
H	Heritage	History: What culture(s) is the farmer from? What is the work culture at the farm? What are guiding assumptions, perspectives, beliefs, and values e.g. regarding technology usage and sustainability?
R	Risks	What are the farmer's concerns, fears, worries? These go beyond financial limitations, to social risks in the community, climate change, and (free) time concerns?
I	Individuality	Consider personal characteristics (e.g. an open personality), gender (which might affect one's position in the industry), and independence/autonomy (e.g., does the farmer value the connection to animals/crop and resist constrictive technology, or is technology considered a tool that provides more control, or freedom?
V	View forward	What are the farmer's long-term dreams and wishes for the farm, for him/herself, and for the family?
E	Everyone	Who else is involved? Consider everyone. Is it a family farm? How are the parents/spouse/children involved? How is impact on the family a consideration in farm decisions? Also note other relationships (e.g., business partners, advisors).

Figure 28 WE THRIVE items

These elements are explicated by paying attention to certain indicators, asking questions, and having a dialogue. Below are examples of such attention points and conversational approaches:

Before your visit		
W	**World**	You start with this beforehand; prepare your visit by getting a good idea about the farm (size, workers, level of digitalisation, etc).
E	**Earnest**	Read the room: would a more informal approach be ok?

During your visit		
T	**Technological affinity**	With low tech affinity; assure about the support line, low maintenance, impact on other processes
H	**Heritage**	Is there a lot of legacy on the farm (both in technology and beliefs) that may hinder DATSs adoption? Interactions with and trust in institutions can differ amongst countries. This influences the motivation with which farmers will want to comply and/or expose their data.
R	**Risks**	Go through the contractual agreements, data ownership, liability of things go wrong, potential downside of the DATSs, etc.
I	**Individuality**	What are aspects of the work that the farmer wants to maintain as is? Define together what the interaction level with the DATSs should be.
V	**View forward**	For instance, the outlook on succession (often by the children) influences the propensity to innovate.
E	**Everyone**	The spouse may have a more signifcant role in decision-making than first assumed. It might be you have to invest in understanding the behavioural determinants for the spouse, too.

Figure 29 WE THRIVE conversational approaches

7. Conclusion

During the entire QuantiFarm project, thanks to the diligent cooperation of many project partners, WP1 has been able to collect a significant amount of data. This way we have managed to gain a deep understanding of the behavioural dynamics at play around the phenomenon of DATSs adoption, which can be used for informing interventions to guide the process of DATSs adoption and serve as a reference for future research and activities in relation to DATSs adoption.

It is self-evident that DATSs adoption is a complex domain consisting of a myriad of determinants, surfacing at different times, in different magnitudes. Making things more complicated, determinants have different impacts across farmers and farming contexts. By means of the Integrated framework on DATSs adoption and the farmer stories, an attempt was made to create a comprehensive overview of this complex domain. Three main themes were identified as being crucial in the framework and well worth a deeper dive into how they affect DATSs adoption: autonomy, gender, and culture.

The origin of the QuantiFarm project was the conviction that DATSs are a means to support farmers with the pressures they encounter in their work. What the findings in QuantiFarm so far uncover is that there is a group tiptoeing into (more) DATSs 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. Furthermore, we found, based on 23 farm visits in 11 countries across Europe, and 2 surveys amongst all Test Cases, that European farmers whom all deal with the significant pressure of the effects of climate change, more stringent regulations, insecurity about future prospects, and changing consumer demands, could be considerably supported if they would use DATSs that are accustomed to their specific individual needs. This means that farmers, advisors, DATSs providers, and policy makers need to be aligned in their approach across all phases of DATSs adoption, i.e., encounter, consideration, implementation, and usage. In particular, individual farmers, with their own circumstances, needs, and characteristics, require technology that feeds into the way they collect information, make decisions, and do their work. Our actionable guidelines, that encompass the entirety of the insights gathered in the WP1 work, support the farmers in their decision-making process, uptake and usage of DATSs.

8. References

- Adler, M. A. (1993). Gender differences in job autonomy: The consequences of occupational segregation and authority position. Sociological Quarterly, 34(3), 449-465.
- 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, A., Chilczuk, S., Nelson, K., Ruther, R., & Wall-Scheffler, C. (2023). The Myth of Man the Hunter: Women's Contribution to the Hunt across Ethnographic Contexts. PLoS One, 18(6), E0287101. - Google Zoeken. Accessed November 6, 2024.
- 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.
- Best, D. L., & Williams, J. E. (2001). Gender and culture. The handbook of culture and psychology, 195-219.
- Block, K., Croft, A., De Souza, L., and Schmader, S. "Do People Care If Men Don't Care about Caring? The Asymmetry in Support for Changing Gender Roles." Journal of Experimental Social Psychology 83 (2019): 112–31.
- Boerenverstand (2021). S2-E03. HP Prangsma: De Boer die wil blijven boeren [podcast].
- Brandth, B. (2002). Gender identity in European family farming: A literature review. Sociologia ruralis, 42(3), 181-200.
- Brandth, Berit. "Gender Identity in European Family Farming: A Literature Review." Sociologia Ruralis 42 (March 7, 2003): 181–200.
- Broomfield, Andrea. "The Forgotten Female Aesthetes: Literary Culture in Late-Victorian England." Clio 30, no. 3 (Spring 2001): 364–70.
- Chen, B., Vansteenkiste, M., Beyers, W., Boone, L., Deci, E. L., Van der Kaap-Deeder, J., ... & Verstuyf, J. (2015). Basic psychological need satisfaction, need frustration, and need strength across four cultures. Motivation and emotion, 39, 216-236.
- Clowes, Lindsay. "The Limits of Discourse: Masculinity as Vulnerability." Agenda: Empowering Women for Gender Equity 27, no. 1 (95) (2013): 12–19.
- Copeland, A. J., & Agosto, D. E. (2012). Diagrams and relational maps: The use of graphic elicitation techniques with interviewing for data collection, analysis, and display. International Journal of Qualitative Methods, 11(5), 513-533.
- Croft, A., Schmader, T., Block, K. "An Underexamined Inequality: Cultural and Psychological Barriers to Men's Engagement With Communal Roles -, 2015." Accessed November 6, 2024.
- 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. (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., Bagozzi, R.P., Warshaw, P.R. (1989). User Acceptance of Computer Technology: A Comparison of two Theoretical models. Management Science. 35(8), 982-1003.

- 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.
- "Distancing from a Stigmatized Social Identity: State of the Art and Future Research Agenda on Self-group Distancing - Veelen - 2020 - European Journal of Social Psychology - Wiley Online Library." Accessed November 6, 2024.
- Dutra-Thomé, L., Marques, L. F., Seidl-de-Moura, M. L., Ramos, D. D. O., & Koller, S. (2019). Autonomy development: Gender and age differences from adolescence to emerging adulthood. Acta de investigación psicológica, 9(2), 14-24. Adams, W. C. (2015). Conducting semi-structured interviews. Handbook of practical program evaluation, 492-505.
- 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.
- "Gender Socialization and Identity Theory." Accessed November 6, 2024.
- Hekkert, P., & van Dijk, M. (2011). Vision in design: A guidebook for innovators. BIS.
- Hofstede, G. (1980/2001). Culture's consequences: Comparing values, behaviors, institutions, and organizations across nations. Thousand Oaks, CA: Sage.
- Hofstede, Geert. (2022, November 5). Dimension Data Matrix. https://geerthofstede.com/research-and-vsm/dimension-data-matrix/
- 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.
- "Index Catalog // Carleton University Institutional Repository." Accessed November 6, 2024.
- Inhetveen, Heide. "Women Pioneers in Farming: A Gendered History of Agricultural Progress." Sociologia Ruralis 38 (December 17, 2002): 265–84.
- Jacobs-Basadien, M., & Pather, S. (2022). The Role of Culture in User Adoption of Mobile Applications for Self-management of Health: A Conceptual Framework. In ICT4AWE (pp. 37-49).
- Jayasekara, D. N., & Fredriksson, P. G. (2021). Culture, intellectual property rights, and technology adoption. The Quarterly Review of Economics and Finance, 80, 317-330.
- Jung, Ae-Kyung, and Karen M. O'Brien. "The Profound Influence of Unpaid Work on Women's Lives: An Overview and Future Directions." Journal of Career Development 46, no. 2 (April 2019): 184–200.
- Karimi, S., & Sotoodeh, B. (2020). The mediating role of intrinsic motivation in the relationship between basic psychological needs satisfaction and academic engagement in agriculture students. Teaching in Higher Education.
- Lee, S. G., Trimi, S., & Kim, C. (2013). The impact of cultural differences on technology adoption. Journal of world business, 48(1), 20-2
- Light, J, S. "When Computers Were Women." Technology and Culture 40, no. 3 (1999): 455–83.
- Lim, W., Wong, C., Sneha Rajiv Jain, Cheng Han Ng, Chia Hui Tai, Devi, M.K., Samarasekera, D.D., Ganpathi Iyer, S., and Chong, C.S. "The Unspoken Reality of Gender Bias in Surgery: A Qualitative Systematic Review." PLOS ONE 16, no. 2 (February 2, 2021): e0246420.
- Mackin, Jennifer. "Blue Is For Boys, Science Is For Boys, What's For Girls? A Critical Look at Gender Constructs in Science Toys." Carleton University, May 24, 2016.
- Malik, N. M., & Lindahl, K. M. (2004). System for coding interactions in dyads (SCID). In Couple observational coding systems (pp. 173-188). Routledge.
- Mankad, A., (2016) Psychological influences on biosecurity control and farmer decision-making. A review. Agron. Sustain. Dev., 36 (2016), p. 40

- 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
- McBride, C., Bacchiochi, J. R., & Bagby, R. M. (2005). Gender differences in the manifestation of sociotropy and autonomy personality traits. Personality and individual Differences, 38(1), 129-136.
- 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.
- Meyer, E. (2016). The culture map (INTL ED): Decoding how people think, lead, and get things done across cultures. Hachette: PublicAffairs.
- 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
- 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)
- Nelson, Lise, and Joni Seager. "A Companion to Feminist Geography," n.d.
- Oliver, Kelly. "The Male Gaze Is More Relevant, and More Dangerous, than Ever." New Review of Film and Television Studies 15, no. 4 (October 2, 2017): 451–55.
- Paustian, M. and Theuvsen, L. (2017) Adoption of precision agriculture technologies by German crop farmers. Precision Agriculture volume 18, pages 701–716 (2017)
- Psychological influences on biosecurity control and farmer decision-making. A review
- Rizzo, G., Migliore, G., Schifani, G., & Vecchio, R. (2023). Key factors influencing farmers' adoption of sustainable innovations: a systematic literature review and research agenda. *Organic Agriculture*, 1-28.
- Rogers, E.M. (2003). Diffusion of innovations, 5th ed., New York: Free Press, p. 512.
- Rose, D. C., Parker, C., Fodery, J., Park, C., Sutherland, W. J., & Dicks, L. V. (2018). Involving stakeholders in agricultural decision support systems: Improving user-centred design. International Journal of Agricultural Management, 6, 80-89.
- Rose, D. C., Sutherland, W. J., Parker, C., Lobley, M., Winter, M., Morris, C., ... & Dicks, L. V. (2016). Decision support tools for agriculture: Towards effective design and delivery. Agricultural systems, 149, 165-174.
- Salles, Arghavan, Michael Awad, Laurel Goldin, Kelsey Krus, Jin Vivian Lee, Maria T. Schwabe, and Calvin K. Lai. "Estimating Implicit and Explicit Gender Bias Among Health Care Professionals and Surgeons." JAMA Network Open 2, no. 7 (July 5, 2019): e196545.
- 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
- Su, Rong, and James Rounds. "All STEM Fields Are Not Created Equal: People and Things Interests Explain Gender Disparities across STEM Fields." Frontiers in Psychology 6 (February 25, 2015).
- Syed, H., & Malik, A. N. (2014). Comparative study of effect of culture on technology adoption in Pakistan and USA. The Business & Management Review, 5(1), 42.
- Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories. Procedia Manufacturing 22, 960–967.
- 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.
- Tsjeng, Zing, and Zhi Ying Tsjeng. Forgotten Women: The Scientists. Hachette UK, 2018.
- Van den Broeck, A., Ferris, D. L., Chang, C. H., & Rosen, C. C. (2016). A review of self-determination theory's basic psychological needs at work. Journal of management, 42(5), 1195-1229.
- 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.
- Work Package 1 report: QuantiFarm_ Report on Test Case farm visits M1-M12
- Work Package 4 deliverable: QuantiFarm D4.1 Testing and Assessment Guidelines
- Yalcin, G., & Puntoni, S. (2023). How AI affects our sense of self. Harvard Business Review, 101(5), 130-136.
- Zhang, Y., Weng, Q., & Zhu, N. (2018). The relationships between electronic banking adoption and its antecedents: A meta-analytic study of the role of national culture. International journal of information management, 40, 76-87.

9. Appendices

Appendix A – Reflections on deep dive research techniques

Semi-structured interviews and field notes

The subjects of our interviews were 24 people from 14 farms in 6 European countries. Building on previous QuantiFarm findings that it is rarely solely the head farmer who makes decisions about how to run the farm (including whether to adopt technology/machinery), we aimed to interview two people from each farm. We requested that these be the two people most involved in making decisions for the farm and its future (e.g., the farmer and their spouse, the farmer and their succeeding child, the farmer and their business partner, etc.) The type of relationship we encountered most in our sample was a male farmer and his wife (who was sometimes also a farmer). This predominance of married couples underpins the importance of this research on women's experiences of and opinions on technology.

Although our instructions indicated that we intended to interview two people, the interviews did not always unfold this way. In some cases, the partner could not attend the meeting at the last minute due to, for example, a family obligation. Two examples of this were observed in one farmer's wife, who needed to drive their son to military duty at the time of the interview, and in another farmer's daughter, who had planned to be the secondary respondent but who, at the last minute, had the opportunity to travel for her own research. In other cases, additional people ended up joining the conversation. For example, a farm advisor who was in the building dropped in to say hello and ended up contributing to the discussion. In other cases, when we were interviewing a father-child team, the farmers' wife brought us snacks and refreshments and ended up contributing. In all cases, these adjustments were accepted, but it was indeed welcomed when additional people spontaneously joined the conversation. That is because, in the authors' view, this unplanned involvement reflects the reality of how decisions are made and by whom they are influenced. In all cases, the people joining the conversation were not random passersby but rather close contacts who indeed make up the farmer's immediate network. Observing the natural flow of these interactions was indeed why the choice was made to conduct this series of interviews in the farmers' homes and offices rather than in our office. Although allowing and (even accommodating) these adaptations could ostensibly be seen to muddy the scientific process, embracing such complexity is in complete alignment with and is fundamental to the core of such qualitative research.

Pre-visit questionnaire reflections

The questionnaire sent out before the interviews gave important context for respondents who we would be meeting. It covered the basics, such as names, age, and roles on the farm, so that we did not have to waste time orienting ourselves during the visits. It also allowed us to assess the types of duos that we would be visiting in advance, so that we could plan to focus on certain topics in certain interviews with relevant characteristics. It also gave the duos a sense of significance and demonstrated our interest. This helped lay the groundwork for a positive relationship and a fruitful interview. Lastly, the questionnaire asked a couple of questions about the topics we would be covering: autonomy, culture, trust, and technological affinity. This served the important function of giving repondents a bit of notice about what the conversation would entail. Farm visits typically focus much more on the farm itself and pivoting to somewhat more "academic" questions can be unsettling and challenging, especially when caught off guard. Therefore, we explained in our initial invitation email that the conversations would centre on understanding their approach to making decisions about the farm and their experiences with and opinions of technology. We also requested to speak with not only the farmer but with the two people

most involved in making decisions about the farm. Then, before the visit, we sent out this to further illustrate the types of topics that may come up and to kickstart reflection on these themes.

Behavioural coding protocol reflections

The behavioural coding protocol was a valuable aspect in our interview methodology because it prevented tunnel vision being put on the words being spoken. The protocol kept our attention open to non-verbal communication and partner dynamics. After each interview, the researchers would first fill out the protocol individually and then come together to discuss it and any discrepancies. Typically, overlap was strong in researchers' scores with only few minor differences in ratings. Several observations were made including that women's body language sometimes opened up during their individual interview, whereas men's tended to be more stable across the dual and individual portions. This could be theorized to be related to gender roles related to taking up space or to men tending to have a more central role on the farm (as primary farmer). It supports that there may be value in talking to women individually to ensure equal airtime and freedom to speak. This is, of course, a generalisation and related to the widespread and well-documented pattern that women tend to spend less time talking than men in meetings. The behavioural coding protocol also tuned researcher attention to the compatibility between the partners and to aspects of their collaboration and communication, which could be further explored in the conversation. Overall, the exercise of including this protocol allowed us to maximise the opportunity of interviewing in-person, in the respondents' space, and was instrumental in gleaning as complete a picture of the decision-making dynamics as possible within the timeframe of our visits.

Relational map technique reflections

The relational map technique was a valuable tool in our deep dive visit toolbox. It allowed us to better engage with different types of people, some of whom had been shier to speak in the interview portion. Some seemed more comfortable speaking when they had something concrete to focus on and work with on the table, rather than sitting with eye contact. Additionally, it sparked motivation in some, who were in their stride when demonstrating their entrepreneurial spirit through diagram-making and active presentation. It also allowed us to overcome language barriers by providing visual communication and context. The technique allowed the conversation to seamlessly transition from discussion of the farm at present to visions of it in the future, invoking a futuring activity in an approachable way. The technique propelled conversations by allowing the researchers to probe priorities (e.g., adding workers first, indicating that they are viewed as central). Interestingly, expected gender differences were observed in that women tended to focus more on other people, specifically, family, whereas men tended to focus on other factors (e.g., farm components, business). Importantly, multiple repondents commented that they had enjoyed the exercise so much and gotten so much insight out of it that they intended to recreate it with their children as a way of understanding each other's vision of and for the farm. Research programs, such as QuantiFarm, that rely upon citizen engagement should strive to create value for the repondents given their invaluable input and efforts; the relational mapping technique was one way this was achieved in the current research. This activity, known for use with children, creates a forum for intergenerational discussions in a creative and low-stakes way. Last, the relational mapping technique served the simple yet crucial functions of breaking up the hours-long interviews, making them enjoyable, and renewing repondent attention and energy. The researchers agree that although the technique was not applied in the traditional sense (in that formal analysis of the maps was not performed), the technique fully served its function and should be retained as a tool for future such interviews.

Appendix B – Survey DATS adopter farmers

Survey about the adoption of digital agriculture technology solutions (DATSs)

This survey is meant to be filled out by the farmer, or employee on the farm, that is both familiar with the DATS and has a say in the decision-making to deploy DATS(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 DATS that is the central DATS for your test case in QuantiFarm? NB: the remainder of this survey will deal with this DATS.

Please choose: I..

- ☐ Invest(ed) in the DATS myself
- ☐ Invest(ed) in the DATS together with others

- ☐ Use the DATS, but am not paying for it (i.e. others invested in it)
- ☐ Other:…….

Are you the one that uses the DATS the most?

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

Several data-related tasks can be linked to working with the DATS. Can you please assign to what task, in percentages, you devote the most time when working with the DATS?
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 (DATS), 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 DATS?

You have to drag each item to the space above.

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

When using the DATS 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 DATS meets my requirements					
The DATS is easy to use					
I am satisfied with the DATS					
The DATS helps me to sustainably run the farm (economic, environmental and/or social)					

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

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

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

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

Only monitoring Autonomously

Could you elaborate?.....

[END]

Appendix C – Survey DATS 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 DATS and has a say in the decision-making to deploy DATS(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.

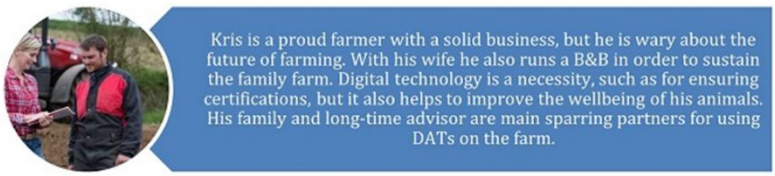
I give explicit permission for the processing of special personal data: ideological and generic economic data. I give permission to reuse my research data for future research in the research area described, provided that it is coded in such a way that it can no longer be traced back to me as a person.

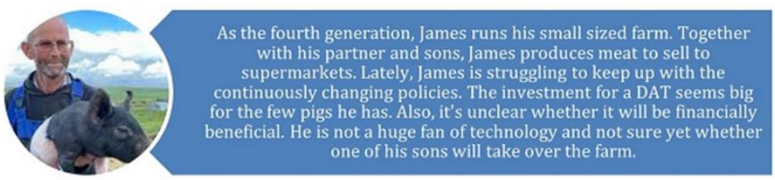
I give permission for the data to be stored and for authorized members of the research team and authorized inspectors to have access to it.

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 (DATS), 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 DATS (e.g. improving yield, reducing costs, ensuring certification)
Ease of use of the DATS (e.g. direct applicability of info, understandable visualisation of data
Recommendations from my colleagues an/or advisors
Trust in the supplier of the DATS
Trust in how the DATS works (e.g. how my data is secured, and that it is up-to-date)
How the DATS 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 DATS(s) on the farm?.....

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

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

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

Only monitoring Autonomously

Could you elaborate?.....

[END]

Appendix D – SFYN research approach

Workshop

Visits to farmers, restaurateurs, 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 30 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[10].

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 meant 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.

[10] 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 31 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); DATSs 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.

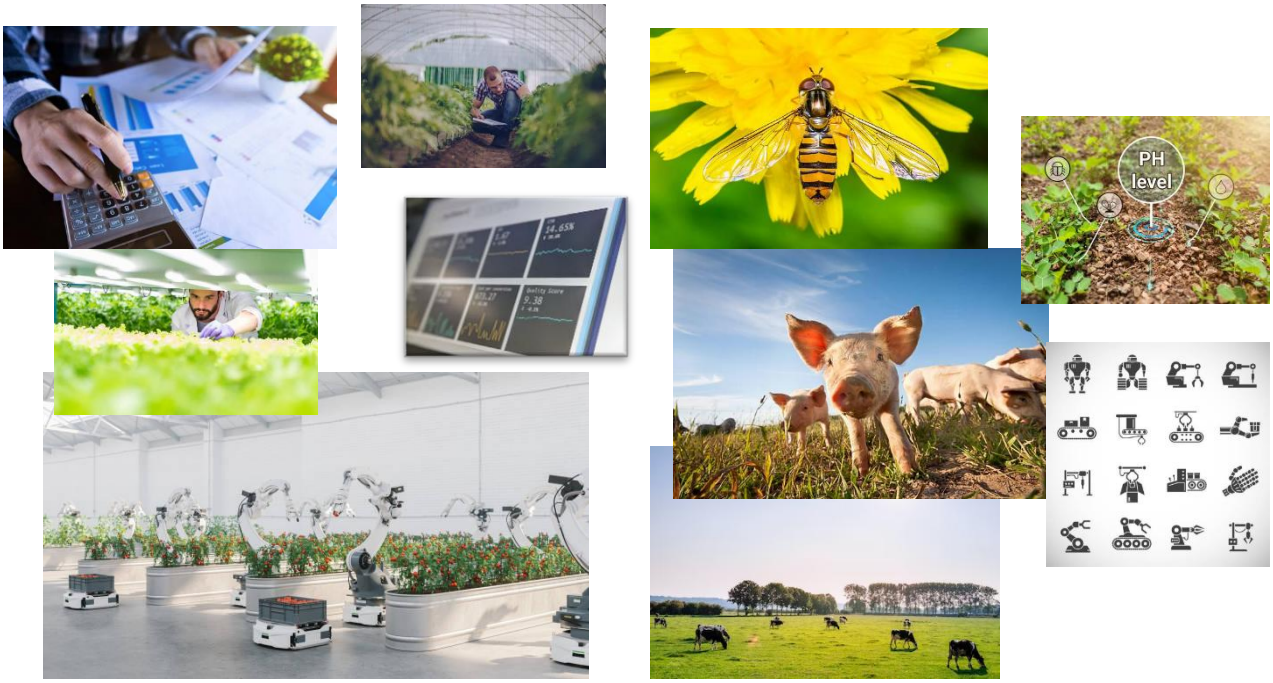
Applied to this research, SFYN collected images which represented either a data driven farm or a non-data driven farm.

Figure 32 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 E – Overview of the farmer storyboards