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ROBS4CROPS

Deliverable 7.1
Report on social impact

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Abstract:	This document presents perceived social and environmental impacts of robotic applications in field crop operations based on a survey of farmers and interviews with key non-farmer stakeholders. Farming robots are expected to provide several operational and environmental benefits. From the farmers' point of view, the major concerns relate to high investment cost, safety, reliability and adaptability to small farm sizes. The non-farmer stakeholders appear to be more concerned about job polarization and job loss, data ownership and privacy, and further consolidation of farming.

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List of Abbreviations and Acronyms	
FMIS	Farm Management Information System
DSS	Decision Support System
LSP	Large Scale Pilot
R4C	Robs4Crops project

1. Introduction

With advances in robotics technology and artificial intelligence, automation in agriculture is nowadays regarded as a promising solution to tackle cross cutting challenges of sustainably feeding a growing population without jeopardizing environmental integrity[1]. Along with other sophisticated technologies such as sensors, cloud computing, big data analytics, and artificial intelligence, robots are expected to let farm businesses be more profitable, efficient, safer, and environmentally friendly (Charania and Li 2020). In spite of some existing evidence on promising perspectives for various autonomous systems (Pedersen, Fountas et al. 2017, Shockley and Dillon 2018, Lampridi, Kateris et al. 2019), autonomous field robots yet have little presence in farming (Sparrow and Howard 2021). Because of the highly unstructured nature of the agricultural environment and the delicacy of the operating agricultural products, the sector has not seen comparable success with robotization as in the automation and manufacturing industry (Zhang, Xie et al. 2020). While autonomous moderately-sized machines are regarded as a prospective way of promoting sustainable production of food, broad expansion of autonomous robots is yet hindered by many challenges where reliability, safety, system complexity and cost efficiency are the top ranking challenges (Rovira-Más, Chatterjee et al. 2015). Moreover, studies show that current regulation (or lack of regulation) about on-site monitoring of field robots is a barrier for adopting robots in many countries (Lowenberg-DeBoer, Behrendt et al. 2021). In Europe, for example, the prevailing regulation requiring 100% on-site human supervision can have a serious implication for the attractiveness of agricultural robots for small and medium farms.

In Europe, there have been efforts to encourage digitization and automation of agriculture through systematic cross disciplinary and cross-national research collaborations and funding. The Robs4Crops project aims to mainstream the use of automated robotic systems in crop farming with primary focus on the most labour demanding and repetitive operations, namely: mechanical weeding, and spraying of chemical crop protection agents. The project is coordinated by Wageningen University Research and involves 16 partners across 7 countries. Robs4Crops aims to mainstream robotic crop farming in Europe through demonstrating integrated use of smart implements, farming controllers and autonomous vehicles.

As a project partner, the University of Copenhagen is responsible for leading work package 7 which has the overall objective of assessing the social, economic and environmental impacts of robotic solutions in field crop agriculture drawing on data from case countries where the project's Large-Scale Pilots (LSPs) are situated; namely, Spain, Greece, France, and The Netherlands. This deliverable report (Del7.1) primarily focuses on assessment of social impact associated with robotics applications in field crop agriculture. As environmental and social impacts are closely intertwined, the report also includes environmental aspects[2] . Introduction of new agricultural technologies including field crop robots involves complex set of **social impacts** (Sparrow and Howard 2021) and impact categories (economic, social, environmental) are interrelated (Antle 2011). In this report, special focus is placed on social impacts.

From a **social impact point** of view, there are many concerns such as reducing employment opportunities, safety, widened inequality, de-skilling, socially unfavourable changes in market/firm structures (threatened prospect for family and small farms and associated further

[1] https://www.idtechex.com/en/research-report/agricultural-robotics-market-2022-2032/837 Accessed on 8 November 2021 at 11.40am CET.

[2] A further analysis of environmental impact for the specific robotic systems in the project will also be addressed later as part of cost-benefit analysis in WP 7.

corporatization of farming) with negative implications for biodiversity, etc. (Sparrow and Howard 2021).

It is argued that the introduction of robots in farming may lead to significant demographic changes in the sense that some jobs – directly or indirectly - could move to completely different regions (Sparrow and Howard 2021) such as the development of software and hardware and other intelligent features like weed detection and route planning systems of which the latter is usually a job conducted by the tractor pilot when doing field operations.

Some of the farms that solely will rely on robots in the future may also be more vulnerable in regard to security and exposed to hacking from random-ware attacks etc. (Sparrow and Howard 2021).

The gender balance may change as some physical hard jobs that usually are carried out by men could as easily be done or replaced by women – although at the contrary some jobs in relation to software development etc. so far have appealed more to men than women.

Labour displacement is a critical social concern with agricultural technologies and more so with robots (Marinoudi, Sørensen et al. 2019). Field crop robots are believed to provide promising opportunities to improve input use efficiency (Gonzalez-de-Santos, Ribeiro et al. 2017).

The issue of worker safety is inherently of great concern in agriculture due to a variety of arduous tasks (Benos, Bechar et al. 2020). While on the one hand, robotic applications are argued to predominantly take over those arduous tasks, ensuring safety with growing human-robot interaction remains a pressing challenge (Aletdinova, Kravchenko et al. 2017, Gonzalez-De-Santos, Fernández et al. 2020). Simpson (2014) points out that with increasing deployment of robots replacing humans, there is a risk of weakening social capital.

Concerns about data ownership and privacy, lost or reduced autonomy of the farmer, and increased need for specialized knowledge are among the social challenges associated with robotization. In the environmental domain, changes in amount of fuel, chemical fertilizers and plant protection materials, emission of chemicals, and soil compaction deserve attention. Agricultural robots – which are often smaller and lighter than conventional farming equipment - are expected to contribute to reduction of GHG emissions from better and more precise route planning, reduced soil compaction due to lighter equipment and with advanced farm information systems they may help to reduce the use of crop protection measures such as herbicides and fungicides (Duckett, Pearson et al. 2018). In order to develop mutually beneficial robotic solutions and adapt market models, there is an urgent need to elicit the main concerns, motives, and expectations of end-users: primarily farmers, but also farm workers, farm contractors, manufacturers and dealers of farm machinery, insurers, and bankers.

The **objective** of doing this social impact assessment is to identify major concerns, challenges and opportunities, and inform management strategies to minimize negative impacts and maximize potential positive impacts associated with the robotic implementation in the four R4C LSPs.

This report provides basic understanding of these issues based on farmer surveys conducted in project case countries and interviews with other key stakeholders. Results presented from the survey are based on responses from 40 farmers (20 from Greece, 13 from France and 7 from Spain) collected during October to November 2021. The non-farmer interview part included a total of 14 informants.

2. Methods

2.1. Impact assessment methodology

Social impact assessment is a methodology to assess the social impact of a new technology, intervention or industrial process.

Burdge and Vanclay (1996) defined social impact assessment as " *the process of assessing or estimating, in advance, the social consequences that are likely to follow from specific policy actions or project development…*". As noted in … assessment of social impact requires experience and observation in particular farming systems.

It may both include either planned interventions such as the development and implementation of autonomous systems on farms or unplanned interventions like natural disasters such as climate change with higher temperatures, heavy rain, flooding etc. The final aim of a **Social impact assessment** is to avoid any negative social consequences from introducing a new technology/intervention or to enhance the positive impact from the same technology. In principle, social impact assessment includes everything that affect people as long as it is valued to be important for a certain group of stakeholders. The goal is in short to obtain a social sustainable development of projects (Vanclay, Esteves et al. 2015).

A social impact assessment may take different forms depending on the type of technology, technology readiness level, environment and likely influence on the surrounding society. Some technologies are at a supply driven stage others are at a more mature and demand driven stage.

It often involves the view of different stakeholders that can be involved as part of direct interviews or by involving stakeholders or even lay-people and citizens in different fora to better understand the impact and consequences of a new intervention.

Given the fact that some of the robotic systems under investigation are not directly available at the market yet or at a pre-commercial stage, our approach will be a mixed approach, which to some extent implies the involvement of experts to assess both technical and social impact of an intervention.

Unlike a **partial** assessment approach where only one kind of stakeholder is involved we apply a **holistic approach** where several kinds of stakeholders that might be interested or might be influenced by the technology are included – it requires at the end that weighting and judgement of the various arguments and conclusions are brought together (Pedersen 2003). The impact assessment approach used in this study is guided by literature (Antle 2011, Rodrigues and Rituerto 2021) and adapted to the specific context at hand. Depending on the factual technical uncertainty and value dissent an impact assessment could be relevant to clarify any uncertainty about the facts and provide guidance in regard to a possible development path of a technology or intervention.

Impact analysis can be divided into: social impact (e.g. change in labour use), environmental impact, ethical impact and cultural impact analysis. In line with Sparrow and Howard (2021), we consider social impact in terms of the following categories: labour, cultural, environmental, safety and ethics. According to Henriksen (1997), (Pedersen 2003). It may also involve an assessment of external costs and benefits. However, it often involves non-economic impacts, implying a need to involve stakeholders in the assessment process.

Issues in relation to ethics will also be dealt with in more detail in del. 7.2 and issues about cost and benefits will also be dealt with in del. 7.3 and 7.4.

Steps in social impact assessment

A first step is to describe the intervention plan or technology that is expected to take place or applied. A second step is to describe the environment and area in which the intervention or technology is expected to be applied - and a third step, which is also the core part of the assessment, is to identify the potential social changes and impact and likely consequences of this intervention or technology in a given environment. Finally, a forth step may include a plan to deal with the social impact. A social impact assessment is often followed by implementation and management strategies and a plan to monitor social change and impacts.

In this study our technology or intervention will focus on robots and autonomous systems. Theenvironment and area in which the technology is applied and targeted, is the agricultural sector and surrounding society.

Peláez and Kyriakou (2008) defined robot as "...part of a system of advanced automation that intends to recreate human behaviour, developing duties without human intervention, and with a determined level of intelligence and learning".

Our focus will be on the four sites in Europe where LSPs are implemented. To assess the potential social impact of introducing robots in the different agricultural settings, we collected data from several stakeholder groups and use knowledge and experience from other studies and projects on the implementation of field robots.

The methodology approach is based on three types of data sources given the characteristics of the technology and the different stakeholders that may be influenced by agricultural robots (firstly farmers) but also other non-farm stakeholders that may be influenced in the supply chain or stakeholders that have expert knowledge about the development of the technology and its implications. The following type of data sources have been applied in this study to reveal any potential social impact and changes:

1. **Survey of farmers** in countries where the R4C LSPs are implemented (France, Greece, Spain and the Netherlands).
2. **Targeted interviews** with key-persons including, experts in smart farming technology, farmers association, robot developers to assess the social impact on different user groups at the supply and demand site of this new intervention.

Based on the key learnings from these sources, we attempted to outline a **plan with recommendations** to deal with the implementation of robots and autonomous systems.

2.2. Data

Data for this study was collected through a combination of farmer surveys and interviews with non-farmer stakeholders. Identification of impact categories was inspired by available literature (briefly summarized in the introduction section) which served as a basis for survey questionnaire and interview guideline preparations.

Farmer survey

As the project's the large-scale pilots (LSPs) are still under preparation and cannot serve as a source of information, we assessed farmers' perceptions and expectations of the phenomena in the project case countries. Given that farmers are key stakeholders and end-users of the robotic technology, we sought to collect a rich data which provides valuable insights on several aspects of their farming. A survey method was chosen to get responses from as many farmers as possible while covering several aspects/questions for better understanding.

It was planned to have about 20 complete farmer surveys from each case country (Spain, France, Greece and The Netherlands) to obtain a representative range of responses. In France, a total of 21 surveys were distributed out of which 13 complete/valid survey responses were received. In Spain, 7 filled surveys have been received and used in this study[3]. In Greece, 20 farmers were approached and all have filled in the survey. However, due to practical challenges in survey distribution and implementation, no survey responses from the Netherlands could be included in this report[4]. The choice of potential survey respondents was made purposively to reflect the type of crop production targeted in each of the pilot countries; i.e., apple orchard in Spain, table grape in Greece[5] and vine grape in France, and potatoes/onions in Netherlands.

The farmer survey data is a cross-sectional survey collected through a structured questionnaire during the period October and November 2021. The questionnaire was first prepared in English by Robs4Crops team at the University of Copenhagen with inputs/comments from project partners, mostly the pilot site managers from the respective case countries. Contact persons and pilot site managers then translated it to the respective national languages and implemented the data collection with direct contact with the sampled farmers. This approach was chosen as it enables the best possible use of local partners' networks and follow up schemes besides dealing with language barrier.

The survey aims to understand the state of robotics applications in agriculture; learn about the experiences, perceptions, expectations, concerns, and challenges of farmers; and get useful insights into social and environmental impact of robotic applications in crop farming.

The survey covers the following themes:

- Farmer demographics and experience with farm management
- Farm characteristics
- Machinery use and working capacity
- Human resource and time allocation for field, office and learning activities
- Major challenges in farm management and/or using conventional machinery
- Experience/exposure to robotics applications in field operations in crop farming
- Farmers' expectations, concerns, challenges, and perceived/anticipated opportunities for robotic crop farming
- Use of Farm Management Information Systems (FMIS) and precision farming practices

Information about social and environmental impact of robotics is elicited from responses on three sets of questions in the questionnaire:

- Expectations about the potential impact of agricultural robot on selected social and environmental indicators
- Motives for using agricultural robots
- Main concerns with agricultural robots

[3] Note data collection in Spain is in progress and any additional data will be incorporated in future dissemination.
[4] Data from the Netherlands will be included as part of dissemination and reporting activities at a later stage in the project.
[5] As inferred from responses to Q8 and Q10 in the questionnaire, while the Greece sample is more diverse in terms of the type of crop production though many respondents produce table grape.

Indicators used to elicit social impact are the following (see also appendix):

- Worker safety (risk of injury and/or death) from tractor turn over
- Exposure to tractor vibrations
- Expected change in employment opportunities
- Safety and reliability of robots
- Labour market disruption
- Farmer autonomy
- Need for specialized knowledge
- Data ownership and privacy
- Adaptability to small farm sizes

Indicators related to perceived environmental impact include:

- Soil compaction
- Emission of chemicals
- Incentive to reduce environmental impact
- Change in the amount of fuel, chemical fertilizers and plant protection materials

Due to the small sample size, a descriptive approach to data analysis is used. Data is presented in the form of histograms and tables with mean values and/or percentages where believed fitting.

Non-farmer stakeholder interviews

We interviewed 14 key non-farmer stakeholders including farming equipment producers, dealers, researchers, advisory services, and R4C LSP site managers. The interviews were conducted in January 2022 and all interviewees agreed to be cited in this report. The questionnaire for the farmer surveys and the guiding open-ended questions for the interviews are provided in the appendix.

The interview participants were purposively selected from a range of stakeholder groups which are believed to have key roles in robot research, development, manufacturing, test, and/or advisory services. To gain insights into priority concerns, challenges and opportunities and develop context relevant management strategies for the R4C project LSPs, site managers in the respective LSPs have been interviewed. Interviews were conducted during 14-26 January 2022. All interviewees were presented with all questions. However, there were a difference in the interview approach and/or focus between R4C site managers and the rest of the interviewees as the latter answered the questions in general terms about robotic use where the site managers had a focus on the impact on the specific site.

3. Results from farmer survey

To provide context, the analysis begins with an overview of farmer characteristics, main challenges associated with use of conventional machinery and farm management practices, experience and/or perception about agricultural robots, plan to invest in robotic solutions, perception about availability of adequate information/advice on robotics, familiarity with (and/or plan to use) precision farming techniques & Farm Management Information System (FMIS). This section provides an overview of the findings from the survey focusing on information relevant to social and environmental impact issues. An overview of the social impact seen from non-farmer stakeholders' perspective is also presented.

3.1. Overview of data from farmer survey

3.1.1. Farm and farmer characteristics

The type of crop production the surveyed farmers are engaged in corresponds to the crop type targeted in the LSPs in the respective case countries: table grapes in Greece, apple orchard in Spain and vine grapes in France (as mentioned above, survey results from The Netherlands are still pending).

Table 3.1 presents an overview of the surveyed farmers and their farm characteristics. In the table GR, FR and SP represent Greece, France and Spain, respectively.

Table 3.1 Summary of overview data characterizing the sample

Variable	Question number*	Number of responses	Key responses	Remarks
Farmer age	1	27**	Mean=50 years	GR=48; SP=55

Gender	2	40	93% male	
Number of years in farm management	5	40	Mean = 22 years	FR=13; GR=24; SP=31
Farm area	7	38	Mean=34 ha	FR=55; GR=13; SP=48
Difficulty to find enough labour when needed	13	37	78%	FR=92%; GR=82%; SP=43%
Participation in field technology events***	6	40	55% participate occasionally, 45% participate often	FR=92% participate occasionally; GR= 65% participate often
Availability of adequate information/advice about robotics applications in agriculture	35	38	66% answered No	No: mostly the case for the Greece and Spanish sample
Use of FMIS	38	40	41% using FMIS; 38% never tried FMIS	Majority of users from France sample
Current use of robotics	18	35	11%	2 farmers from France and 1 each from Spain and Greece
Plan to invest in agricultural robots in the coming 10 years	24	37	57% answered 'Yes'; 19% answered 'No'; 24% answered 'I don't know'	

*Question no. refers to which question number it is from the questionnaire (see appendix).
** No age data for the sample from France.
***Workshops, trainings, conferences, agriculture-fairs

There is considerable difference in farmer age, farm size and farmer experience in farm management across the countries in the sample.

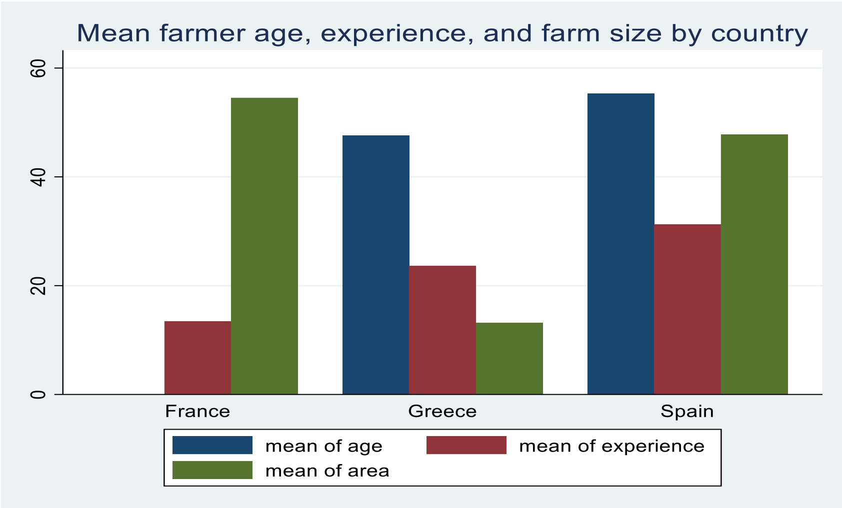

Figure 3.1 Mean values for farmer age (years), experience (years) and farm size (ha) by country of respondent. Note: the number of observations over which the mean values are calculated are 20, 13, and 7 for Greece, France and Spain, respectively.

In France, on average, respondents have few years of experience in farm management (13 years), yet operate relatively big farm sizes (55 ha). Farmers from Spain reported the longest experience (31 years) in farm management but operate medium farm sizes (48 ha). The sample from Greece operates the smallest farm size (13 ha) while it stands in the middle in terms of years of farmer experience in farm management. The sample from France constitutes young farmers (in terms of years of experience) operating relatively bigger farm sizes.

Nearly 78% of the surveyed farmers mentioned that they have difficulty to find enough labour when needed.

All the 40 farmers participate in field technology events such as workshops, trainings, conferences, and agriculture-fairs.

About 41% are currently using FMIS whereas 38% have never tried FMIS. The majority of FMIS users are from the French sample.

Current application of robotic solutions for crop farming among the surveyed farmers is negligible with the exception of 4 farmers allotting a fraction of their farm area for robotic applications. When asked whether they plan to invest in robotic solutions in the coming 10 years, about 57% said 'Yes', 19% 'No' and the rest 'I don't know' (percentages are out of 37 farmers who responded to the question). About 66% stated that they do not think adequate information/advice about robotics applications in agriculture. The issue appears to be mostly the case for the Greece and Spain samples.

3.1.2. Challenges with conventional machinery and farm management

Farmers were asked to choose from a list of challenges associated with the use of conventional machinery (Q15) and current farm management (Q14) with the possibility of choosing as many of the options listed as applicable in each question. The main challenges associated with the use of conventional machinery are: high labour demand (60%), soil compaction (50%), inconvenience to transport (43%), lack of flexibility (28%), and lack of compatibility (20%). The data shows that the main challenges (in order of decreasing importance) are: affordability of available technological solutions (65%), precise estimation of crop water and nutrient status within the field (58%), access to relevant technological solutions including Decision Support Systems (DSS) (28%) and access to relevant and timely information (18%).

Table 3.2 Challenges with using conventional machinery and farm management

Farm management challenges (Q14)	Percentage (out of 40 respondents)	Challenges with using conventional machinery (Q15)	Percentage (out of 40)
Affordability of available technological solutions	65	High demand for labour to operate the machineries and also perform tasks that cannot be handled by those machineries	60
Precise estimation of crop water and nutrient status within the field	58	Soil compaction due to heavy machinery	50
Access to relevant technological solutions including DSS	28	Inconvenience to transport from field to field	43
Access to relevant and timely information	18	Lack of flexibility to perform different operations	28
Cost of staff training to be able to use states of the art technological solutions	10	Lack of compatibility among machinery/implements from different suppliers	20
Complexity of available technological solutions	8		
Other challenges	5	Other problems/challenges	8

3.1.3. Priority features of agricultural robots sought by farmers

Survey participants were provided with a list of features/ and characteristics of agricultural robots and asked what should be the three most important features of agricultural robotics. They were asked to rank the three most important features (Q30). A summary of responses to this question are presented in Figure 3.2.

As shown in Figure 3.2, the three most frequently chosen features of robots are capacity to work longer hours (75%), ability to accommodate several attachments (60%), and the ability to perform under different weather conditions (55%). Weather insensitivity and ability to perform under different weather conditions, ability to work long hours, safety (and versatility) are ranked as the first, second and third priority features, respectively.

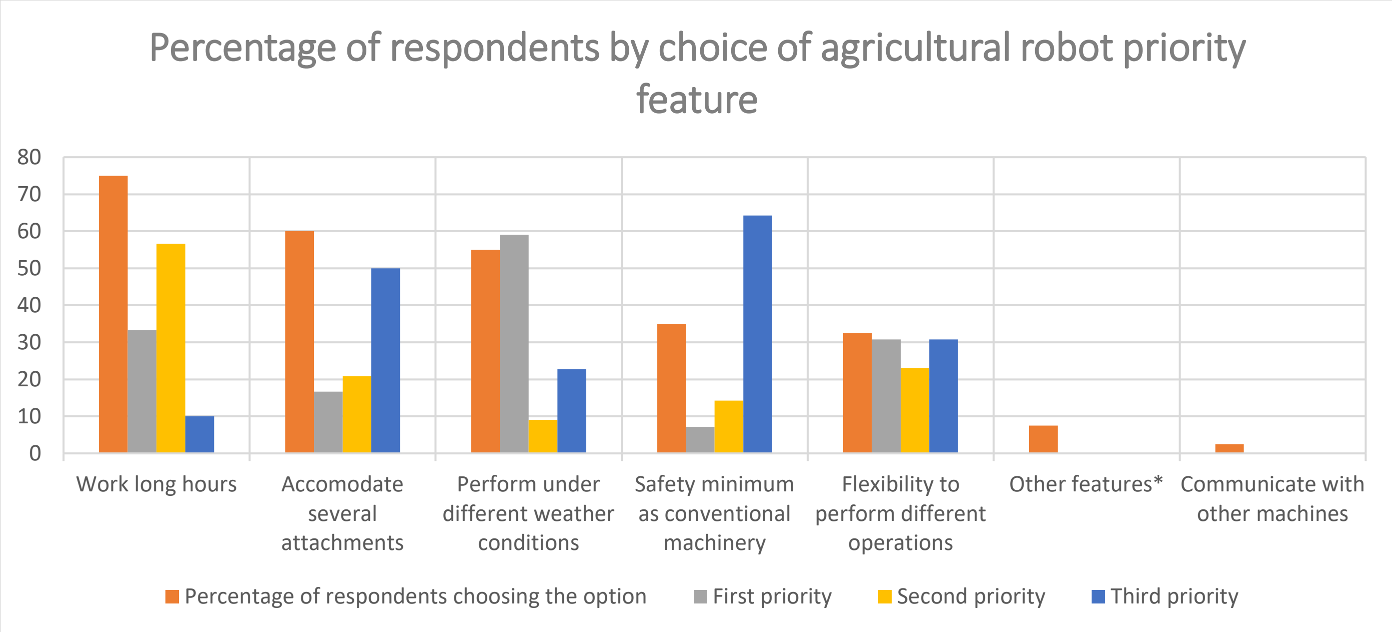

Figure 3.2 Priority features of agricultural robots according to surveyed farmers

3.2. Social and environmental impact seen from farmers' perspective

3.2.1. Expectations about impact of agricultural robots

Survey participants were provided with a list of economic, social and environmental indicators and asked to mark whether they think Agricultural robots would have an increasing/decreasing impact on each of the indicators (Q21 in the questionnaire). In literature, it has been documented that farmers' evaluation of advantages and disadvantages of field crop robots differs by farm size, farming system (conventional versus organic) and occupational structure (part-time versus full-time) as documented in (Spykman, Gabriel et al. 2021).

As can be read from Table 3.3, majority of the survey respondents expect agricultural robots to increase crop quality, gross margin, net profit, resilience to shock and decrease labour demand, exposure to tractor vibration, soil compaction, emission of chemicals.

While a reduction in labour demand can possibly be associated with economic gains for farmers (farm owners), this also gives rise to a social concern in the form of diminishing employment opportunities for farm workers. On the other hand, reduction in worker exposure to tractor vibrations can be regarded as a desirable social impact of agricultural robots. As far as expected environmental impact is concerned, reduction in soil compaction and chemical emission are on top of farmers' expectations in our sample.

Table 3.3 Farmers' expectations about potential impact of agricultural robots on selected social, environmental and economic indicators

Indicator	Number of respondents	Percentage of respondents by expected change category			
		Increase	Decrease	No impact**	No idea
Crop yield	37	30	5	8	57
Number of farming implements	37	27	46	3	24
Crop quality	36	56	6	8	31
Gross margin	37	59	11	0	30
Net profit	38	55	11	0	34
Labour demand	35	9	69	3	20
*Optimal input application	36	31	39	3	28
*Worker safety	38	34	37	0	29
Worker exposure to tractor vibrations	36	8	67	0	25
Resilience to external shocks	36	53	3	3	42
Soil compaction	36	11	64	0	25
Chemical emissions	35	6	51	0	43
Ease of documentation	37	14	14	8	65

*There are some concerns with the question formulation (phrasing) of indicators: "Worker safety (e.g. chemical exposure, injuries/deaths from tractor overturn)" and "Optimal input application (e.g., seed, fertilizer, pesticides, insecticides)". Some respondents may have just thought of worker safety improvements while others might have interpreted as incidence of chemical exposure and/or injuries due to tractor overturn. Similarly, some respondents may have thought of 'improvements in optimality of input application' while others may have understood it as change in the amount of the inputs provided in bracket. As such, interpreting the observed data on these entries is challenging.

** The 'No impact' option was not provided in the questionnaire. Some respondents added this category in a comment field.

Moreover, farmers were asked how they think the use of robots will change total amount of farm inputs (fertilizers, seed, crop protection materials, growth regulars) on their farm (Q22). Responses to this question are summarized in Table 3.4

Table 3.4 Farmers' expectations about the effect of agricultural robot use on amount of farming inputs

Input type	Frequency	Percentage of respondents by expected change category		
		Decrease	Increase	No change
Fuel	37	78	11	11
Nitrogen	33	9	3	88
Phosphorus	33	6	3	91
Potassium	33	6	3	91
Other fertilizers	33	6	12	82

Lime	33	6	9	85
Herbicides	34	88	0	12
Insecticides	35	34	14	51
Fungicides	34	32	18	50
Seed	30	47	7	47
Growth Regulators	32	16	9	75

Most of the farmers expect agricultural robots to reduce the amount of fuel, herbicide, and seed.

3.2.2. Motives for agricultural robot use by farmers

According to responses to the question "why would you like to invest in robotics? (Q25)", the three most cited motives/reasons to invest in robotic solutions are: to save labour cost (55%), to increase profit (35%), and to reduce environmental impact (30%). Fascination with the technology and need to replace existing machinery are each chosen by 10% of the respondents as additional reasons to invest in robotics. Major motives/priorities for field crop robots could systematically be different between large scale and small scale farm operators as found in Spykman, Gabriel et al. (2021).

3.2.3. Main concerns with agricultural robots among farmers

Surveyed farmers were asked what concerns they have about use of robots in farming (Q34) with the possibility of choosing multiple options from a list provided and also an open space to add other concerns not listed. The most frequently cited concerns (in decreasing order) are: high investment cost, safety and/or reliability, adaptability to small farm sizes, ownership and privacy of data, need for specialized knowledge and low driving speed of robots.

Table 3.5 Farmers' concerns about agricultural robots

Type of concern	Number of respondents	Percentage of respondents (out of 40)
High investment cost relative to conventional technology	31	78
Safety and/or reliability	24	60
Adaptability to small farm sizes	24	60
Ownership and privacy of data collected by robot	8	20
Need for specialized knowledge to operate and maintain robots	7	18
Low driving speed of robots according to existing regulations and standards	7	18
Human worker replacement by autonomous robots[6]	5	13
Lost/reduced autonomy of farmer	4	10

[6] In the questionnaire, this was phrased as "Labour market disruption by replacing human workers by autonomous robots".

Consumer acceptance of my crop (perceived crop quality) may decline	3	8

About 20% of the surveyed farmers reported to be concerned about ownership and privacy of data collected by robots. When asked who they expect to be the primary processor of data from robots (Q36), the majority (81% of 37 farmers who answered the question) marked themselves and/or their employees with only the remaining fraction expecting other entities (farm input providers/dealers, consultant, robot manufacturer) to primarily assume the role.

Labour market disruption does not seem to be a concern as such among the surveyed farmers. From a farm owner/operator point of view, potential loss of job may not be an issue of considerable concern in the sense that they consider themselves as employers rather than employees. In this respect, there is a need to hear the voices from other stakeholders to assess the market impacts of agricultural robots and other social impacts.

4. Results from interviews with non-farmer stakeholders

This section summarizes the findings from interviews with key non-farmer stakeholders about their view on the social impact of implementing robotic systems in the agricultural sector. In principle, the non-farmers' view on social impact is presented as their view (quoting from interviews) and organized according to the specific questions that was asked at the interviews. All stakeholders were asked the same questions (see guideline in the Appendix). The questions were related to social impact and labour use, cultural and political impact, economics, environment, safety aspects, data handling and ethics etc.

Social impact and labour use

According to **Ard Nieuwenhuizen & Fred Kool** farmers are waiting for the robots, but there are also some concerns in regard to social impact and labour use. Robots can do the hard work on the farm and there is a currently a lack of workers at the moment. This is an attraction of using robots **(Ard Nieuwenhuizen & Fred Kool).** The robots will help in many ways in plant production and according to **Mette Walter**, especially when it comes to labour shortages**.**

Rita Hørfarter stresses that there is a growing problem of providing labour in the Western economy. It is a great advantage of the robots that they are cheap to operate and can run 24/7. This means a reduced need for labour and employees. Robots may help in reducing CO_2 loads and contribute to a more green agriculture. Perhaps, precisely the precision assignment of pesticides, should be a good place for the robots to make their intake **(Rita Hørfarter).**

However, there is also a social concern about labour loss and a risk that jobs will move from rural to urban areas **(Oriol Serra).** Robots will change the types of jobs in the farming sector, and it will require new skills within IT and management among farmers, **Claus Grøn Sørensen** expect that work will move from manual tasks to IT skills and use incl. electronic devices at the farm. It may also imply a higher degree of inequality among worker groups. Some farmers may not be able to do the job at the farm and they may have to shift to other type of work. It could also create a more stressful time at the farm, where the farmer have to monitor the equipment and use advanced IT equipment – with a new mindset. It may create a higher degree of job polarization, with some jobs that require low skills and other require very high skills **(Claus Grøn Sørensen).**

Robots are designed to conduct repetitive tasks – it is often difficult to find people who will do these type of repetitive tasks. Like grass mowing, pruning of the trees - many farmers would like to avoid this. Another example is weeding, here farmers use either chemical or mechanical weeding with a mower on the tractor– it could take up to 6-8 operations per year. By using a robot you may save spending time on these operations, and you don't need to find a tractor driver **(Suzanne Baron).**

Economic and financial impact

Christian Holts argues that the demand for robots is not yet so great and therefore the company (tractor dealer) has no robots on the sales list, but all the technology associated with the robots is already implemented in the machines and tools sold and maintained by the company. Robots are not something completely different in that sense (**Christian Holts).** A concern from a manufacturing company perspective could be in regard to the economic and financial efficiency of using robots. One concern might also be about the adoption of robots if they are regarded as less easy to use – then it could be a barrier for the market and farmers **(Suzanne Baron).** In addition, robots are relatively expensive and farmers will not be able to afford them without financial help from external partners, such as the government **(Oriol Serra).**

So far, there is a lack of studies that focus on the cost and benefits of using robots. Only a few studies have dealt with this at the moment – but more studies are coming up **(Claus Grøn Sørensen).**

Environmental impact

There are both economic and environmental concerns relating to climate change, such as increase in disease pressure, and more generally an increased risk in crop production. Moreover, farms grow larger so it is harder to do optimal crop protection. Robots can help to make e.g., use of herbicides more effective **(Ard Nieuwenhuizen & Fred Kool).**

Christian Holts argues that robots will definitely have a place in agriculture. It can for example, be a solution to deal with environmental challenges. However we already have more or less self-propelled or software controlled precision tools in agriculture, like New Holland Amazon, Kverneland, Ropa (beet harvesters) etc.
Sowing and cleaning, where great precision is required, are obvious tasks for the robots and also when spraying with pesticides according to **(Mette Walter)** and also specifically when it comes to more effective use of herbicides according to (**Bertrand Pinel**). However, robot companies are not just replacing old equipment but also rethinking what is the best for the soil and environment – it is a kind of a paradigm shift with robots **(Alea Scowill).**

Robots can be a solution to some of the special challenges in organic plant production, such as weed control. According to **Sven Hermansen**, usually new technologies are developed for conventional agriculture. But it is also relevant to see how these technologies, such as robots, can be used in organic plant production. The robots must contribute to a more rational plant production. Here and not least it could reduce the need for labour. In an ecological context, therefore, special focus should be on weed control, where many hours are used today **(Sven**

Hermansen) and not at least suitable here for solving tasks in high-value crops, where a lot of labour is used today argues **(Mette Walter).**

According to **Christian Holts**, there are obvious tasks for many / small robots with for instance weeding. But there is only a short time window for solving such tasks. So what are these weed robots going to do the rest of the year? It speaks for a few / large robots that can be used for many tasks with a tool carriers such as Robotti. **Christian Holts** argue that either must the robot be able to do it all, all year round, or be very cheap and not take up too much space. There is also a great value in a healthy soil and here the robots can probably reduce the pressure on the soil (less soil compaction).
The robot allows for precision assignment. With GPS tracking, it will be easy to check that precision assignment has actually been completed. Data will then be able to be stored - for instance in five years, as documentation that precision assignment has been carried out and pressure on the ground has been reduced **(Rita Hørfarter).**

Cultural impact

Claus Grøn Sørensen argues that robots will imply that you remove the farmer from the direct control of crops and animals. Consumers may also get the perception - that farming will become more industrialized – where plants and crops are just inputs into an industrial production system.

According to **Ole Green,** a major concern about the adoption of robots is - that in the current situation - where farmers make use of tractors – it is usually based on the presence of farmers. With robots there is no presence of people – it changes the way we are thinking in regard to safety issues, economy and legislation. A direct concern is the practical use of robots in the field without being there yourself. In that matter there is a practical oriented concern about what I (the farmer ed.) need to do in my management with robots.

With the introduction of robots, farmers will have more time for farming but they will also be taken further away from the field. The farmer can choose to spend more time in the field getting to know his land better or from the desk **(Alea Scowill).** In addition it is argued that robots in field operations will make other demands on the advice. Not least remote support **(Sven Hermansen).**

It also seems so, that there is a larger conservatism in the North European countries – the opposite is the case in countries like Romania and Check Republic where I have seen a more open-minded approach to use new robotic solutions and technologies **(Ole Green).**

Suzanne Baron also gives an example from wine production in France. By using a robot it may give an incentive for the younger farmers to go into farming. And it could be appealing and easier for younger generations to use robots – and thereby also an insurance for the older generation – that someone in the next generation will take over the wine production. In the view of Suzanne Baron, there appears only small problems in relation to "disruption" as there are adequate services for using robots. Terrana (a French advisory service), is using the robot as a service. Even if the farmer has never used the robot before – it is possible to test the robot before using **(Suzanne Baron).** However, another issue concerns the attitudes of final consumers. Are they ready to accept "robot produced" wine? **(Bertrand Pinel**).

Data handling and transparency

In regard to data handling and transparency, farmers are becoming a kind of "data farmers" – they will know more about their fields with better and more data – at the same time robot companies will also need access to data – therefore there is a need for transparency and more clear rules about who owns the data. Especially outside the EU **(Alea Scowill).**

Farmers are not really worried about data privacy according to **(Oriol Serra).** A similar view is taken by **Ole Green**, farmers expect (the manufactures) to be in compliance with the current legislation – so far we haven't seen any talks about privacy issues and lack of transparency – it is not an argument we have met when doing our demonstrations of robots among farmers **(Ole Green).** Similar, in France, farmers are not particularly concerned, as they already have quite a lot of information that they share with others about farm management – in that sense they are not so much concerned about data handling because they are used to share information **(Suzanne Baron).** Farmers are always asked about the use of data that is collected by the robots (Agreenculture) - and they have to agree open the use of data.. Data at the time being is only about surveillance of the land surface and locating the obstacles etc. So very little information is collected that could be in conflict with GDPR-rules **(Suzanne Baron).**

However, data could be a future problem. Robots are using many kinds of data. This information will go to who? The cooperative? The company producing the robots? We don't know. Issues about regulation and security are relevant. Data pirates can use them to put pressure on farmers **(Ard Nieuwenhuizen & Fred Kool).**

Safety

Safety can be a barrier in the application of robots on farms, but with our system (Agreenculture) we are already using a number of safety features at the moment. First, using the AGC Box the robot stays within a specific perimeter defined as "Safencing" that is obtained with a very accurate positioning system and land survey. Second, the sensors detect obstacles and stop. Third, is the safety edge (bumper) and finally the emergency stop buttons located on top and on the sides of the robot.. In conclusion, the robotic systems have achieved several steps in bringing it into the farms in a safety way – and farmers see an interest to use the robots **(Suzanne Baron).**

According to **Han Hilbrands,** safety should not be a problem. You have to do a risk analyse when you use the robot. That is all. Dutch farmer's using robots do not pay a higher insurance. It seems that insurance companies are eager to increase and ease the farmer's use of robots and new technology (**Han Hilbrands).**

Political

From a political point of view, this system may require large investments, and it may change the political power, you will need capital instead of labour. To deal with this it must be possible to develop small scalable robots, to overcome this problem of technology **(Claus Grøn Sørensen).**

There is not much focus on regulation in farming – there are gaps concerning data use and transparency – some companies offers services, but there are gaps in regard to regulation. Farmers that are old and not familiar with applications, don't know what to expect from such apps **(Michael Koutsiaras)** therefore it could be relevant with regulation.

According to **Christian Holst** there is no particular reason to subsidize the sale of specific technologies, so it will be better to provide subsidies to the manufacturers / developers of new, promising technologies and robots **(Christian Holst).**

Suggestions about robotic farming system

Several stakeholders argue that there are two ways to go about developing robots for field operations. A tool where the robot is **designed to solve some limited tasks** where everything (tools, software and the problem) fits well together. Or the robot is intended as a **tool carrier** that can be used for many tasks. Robotti from Agrointelli is an example of an implement carrier - "a tractor without a cabine". Small robots can be better adapted to special environmental areas and spots. Small robots will press the earth less. The robots will contribute to a better working environment, where the farmer avoids tedious / exhausting tasks **(Mette Walter).**

Sven Hermansen also distinguish between the two very different applications of robot technology. Is the robot a tool carrier or a tool? Agrointelli has built Robotti, which is a tractor / implement carrier, while FarmDroid (another robot company) has built a tool that solves two or three tasks (sowing, row cleaning and manure spreading). Farm Droid is a small Danish robot for eg seeding in sugar beets. It weighs 500 kg. It is used for sowing in sugar beets with GPS and without the use of cameras. Then it clears weeds in the beets. It can be moved around with a trailer. It has SIM cards and cameras. It is able to look forwards and backwards - so the farmer can be at home and see that everything is ok. The energy comes from the solar panel on top of the robot. It is agile in terms of application and adjustment. The farmer can repair the robot himself using a camera with mobile connection **(Sven Hermansen).** Not all robots need to be as big as for instance Robotti (3 tons robot from Agrointelli). Maybe there is a special need for smaller robots. However, moving an army of small robots will be a challenge. Some smart solutions need to be devised and developed. High wages and labour shortages will force an increased use of robots **(Rita Hørfarter).** Compared to a traditional tractor, the software takes a higher share of the total cost for the robot. Maybe you should not think of robot as a new tractor, but as new tool for specific jobs. The robot should not necessary be able to do all the things you can do with a tractor (**Han Hilbrands).**

Christian Holts does not see that every single piece of land needs four or five robots to look after the field as a replacement for a large tractor. It will be a logistical problem to manage them and transport them. They must, for example, be refueled with pesticides, water and fuel. Denmark is a bit special in terms of capacity. Timeliness takes up a lot of space. Elsewhere in the EU you can harvest etc. over several months. Here we only have small / short windows. Then the equipment must work and there must be a large capacity **(Christian Holst).**

How do you see the introduction of robots in R4C pilots in terms of strength weaknesses, opportunities, and threats

Strengths

Robots enables a more effective use of pesticides and /herbicides **(Bertrand Pinel).** A major strength of using robots is also that they can help to reduce the need for labour for repetitive tasks. Like mowing, which is very time consuming. Another strength is the capacity for the farmer to work on the farm on tasks with more added value especially on the small and middle sized farms. For some tasks in France for instance, it is difficult to find labour e.g. for driving a tractor **(Suzanne Baron).** A strength is also a more efficient use of inputs with a lower climate impact **(Oriol Serra).**

Ole Green argues that the robot is currently the best solution for practicing precision farming and a more sustainable intensification in the field with all the benefits that may follow with PA - such as site specific application of pesticides, nitrogen savings etc. The robotic platform is the obvious enabler for this. If only labour saving is the issue – then it can be handled by larger machines as well as with robots– but robots can enable farmers to perform precision farming in a better way **(Ole Green).**

Robots can do the tasks that people don't want to do. By using robots you will give the farmer more time to farm - and time to consider what to do in the field and take notice about what happens on the farm – that could be quite beneficial with the extra time gained by using robots. You can change the old and bad habits **(Alea Scowill).**

Basically robots can replace repetitive tasks on the farm, the robot in itself is a tool-carrier – and you are able to mount intelligent tools to harvest all the deferent benefits. By using for instance vision systems you could gain a real benefit from using robots. Then you can obtain environmental benefits in terms of reduced pest application, reduced weeding, etc. with better operations and also reduced soil compaction and energy efficiency improvements **(Claus Grøn Sørensen).**

Image recognition systems are incredibly important for the spread of the new technologies. It is important that the developers and the industry have a lot of data available.

Weaknesses

Today, the main weakness is the capacity of the robots in relation to cost. The farmers do not know the lifetime of the robots, therefore the depreciation calculations may be too pessimistic, resulting in too high area costs for using the robot **(Ole Green).**

Technology is changing fast which in itself can be a weakness – it is also difficult to design/make a robot that can do all tasks at the farm – usually some task will be done with conventional systems. Robots may not be able to consider all these daily observations that a farmer may do - To be aware of the changing weather conditions – spots in the field with water, healthy soils and other things that a tractor driver normally observe in the field **(Alea Scowill).**
Another weakness is the price of the robot – that could be a barrier and the human/machine interface – it has to be easy to use to make it attractive among farmers **(Suzanne Baron).**

Low capacity of robots is a problem at the moment – that will create limitations for different operations. Robots are also currently targeted for specific operations – then it is difficult to optimize the whole system – then you need the traditional system alongside the use of robots – it may be solved by using a contractor next to this for other operations. The main problem is that robots are only used for targeted operations – and we need more examples from cost benefit analysis to show the real net benefits for the farming system. The implementation of robots should be regarded as a system transition and not a single technology transition **(Claus Grøn Sørensen).**

A challenge that the robots must be under supervision. The set of rules is not yet in place and needs to be adapted. The robots must also be easy to move. An increased use of robots in plant breeding will place demands on fields and zoning. This will be a problem if the robots have to be moved manually / by road between many small fields **(Mette Walter).**

With a robot, you are not enforced to see every square meter of the field and you do not see where the problems are in the crop growth. In other words, you miss the finger touch. In addition if you do not observe the robot, you do not see if it is mishandling the crop or should be stopped for other reasons. In addition, the logistics is a problem. How to move the robots around between fields and the farm? (**Han Hilbrands).**

However, the robots can also make it interesting (again) to look after the small areas. It can be a special niche for the robots to look after small otherwise obsolete area **(Rita Hørfarter).**

It is costly to train farmers to use robots and robots to be used by farmers. So it requires a big initial investment, which farmers might hesitate to make. It is not a quick fix to solve labour problem **(Ard Nieuwenhuizen & Fred Kool).**

More specifically, different systems (ISO protocol etc.) is still a problem. Robotti from Agrointelli uses shape files. Standards are needed as/like ISO protocol for tractors. More hours and hectares is the challenge and barrier for the field robots. Farmers have to believe that robots are working and drive straight. In that respect, developers have to focus (even more) on farmers need. Achallenge is not just how to build a robot, but how to build a tool for the farmer. The robots are still not 100 percent reliable. There appears to be a steering problem and the robot cannot always drive straight (**Han Hilbrands).**

There is also a challenge for dealers of new farm equipment and new technologies when new technology is introduced. There is always something that is not reliable or does not work as promised. And it falls back on the seller. Therefore, the seller (the company Mertz, a tractor dealer) will have to take the products back and give a discount on the price.
(Christian Holst)

Threats

The regulation can be a treat as it changes very often **(Suzanne Baron).** Moreover, it might be that people really do not want robots, that the technology is not reliable enough to work in the current farming systems **(Ard Nieuwenhuizen & Fred Kool). Ole Green** from Agrointelli further argues that a potential threat is for instance unforeseen new legislation for using robots – for instance, an example I have seen with drones in Spain – It was decided to ban drones in Spain for some time simply because there have been incidents of unwanted use of drones. The same could happen with robots. For instance, an example could be the introduction of John Deeres very heavy autonomous tractors – an implementation of these systems could make a counter reaction where the public and legislatures become worried about safety issues etc. simply because of the size of the machines – their reaction could be followed by political panic reactions to ban robots in general **(Ole Green).**
In regard to data handling and camera systems. There will be some market thinking. (e.g with Crop Manager, a Danish decision tool for site-specific field management ed.). Data are made available to industry (for a fee) in the interest of farmers. One should always be concerned when collecting data in large quantities of great value to the industry **(Sven Hermansen).**

It takes time to adopt the technology to farming operations **(Alea Scowill)**. It is important to secure safety for other workers: How should the manual and the robotic work be combined? **(Oriol Serra).** In Greece for instance, it might be difficult to mobilize broader interest from end users in the region –because they believe their use is not relevant to them due to high investment costs **(Michael Koutsiaras).** Cybersecurity and risk of hacking of systems are also mentioned as threats **(Bertrand Pinel, Ard Nieuwenhuizen & Fred Kool)**

Job polarization could also be a threat from introducing robots and it may imply that people are mowing from the rural areas. With robots you move the farmer from the direct farming activities to a more industrialized system. The autonomous systems may also harm people and in the short run there may be safety issues to consider – especially when you have humans working with more cognitive tasks alongside the robots. In the future we can expect that robots will take over more cognitive tasks **(Claus Grøn Sørensen).**

Opportunities

Since you are changing the farming system with robots anyway, robots may give an opportunity to be more sustainable and rethink the way farming is carried out compared with traditional farming **(Alea Scowill).**
The robot as a carrier will give the opportunity to monitor and use intelligent systems at the farm. It could be a key solution to make a more sustainable farming systems and a green transition on the farms. Especially coupled with different IoT features it will create direct environmental and operational benefits. A further opportunity is that more and more AI will be embedded in robots and then it will be able to take over more and more cognitive tasks **(Claus Grøn Sørensen).**

Robots will also provide opportunities and improve sustainability in regard to finance, environment, working conditions, safety perspective, improved traceability, improved use of water, nutrient and chemicals **(Ole Green).**

Farmers are interested in new things when they attend demonstrations - and here the end-user is brought closer to the robot. Agreenculture could for instance co-design the robot with the farmers because farmers is a new marked for our company, and the company is already doing so – we try to use already existing tools to be mounted on the robot – and that was a request from the farmers to do so. As such the farmers are involved in the co-design of the systems with existing tools, which also helps to reduce their investment costs **(Suzanne Baron).**

It could be an opportunity to gain from demonstrations, like a chance to lower general skepticism about new technology amongst famers by showing what robots can do **(Oriol Serra).** This is also recommended by **Michael Koutsiaras** that argues that there is a long list of measurable metrics to keep track of performance of applications. May help to show that use of robots make a difference for the better – show don't tell **(Michael Koutsiaras).**

What do you think would be the 3 most priority impacts/concerns from introducing robots in R4C?

In the following is made an overview of the selected priorities among non-farm stakeholders:

Firstly, **Ole Green** argues that you can gain a more sustainable and better (optimized) use of machines with robots. It is not necessary to use a specialized driver to do the tasks – so you can easily share the system among farmers with robots. Secondly **Ole Green** argues that robots provide a new way of thinking - Like when Henry Ford asked costumers what they want for transporting – they answered "faster horses" – or like today farmers ask for "larger tractors" compared to existing tractors – but in principle people need to see or feel a new system to get new ideas and use it in a new way. Thirdly, **Ole Green** argues that there is a lack - among farmers - in regard to a sense of urgency, which is a concern. Farmers still can't see the damage they make today - like degradation of soils – it is not taken into account. With robots the farmer can be a climate positive actor – robots and precision farming may imply – in my view - that farming can be carbon positive and not just climate neutral **(Ole Green).**

Alea Scowill argues that farmers lack trust in robots – companies need to show the benefits in a trustworthy manner. Secondly **Alea Scowill** argues that labour shortage is a problem – people don't want to do the hard work – so here robots can help and fulfill that need. Finally, it is pointed out that technology develops very fast – it can be a problem to handle the fast development – so it is important that farmers don't need to buy a new robot every year or update the technology **(Alea Scowill).**

Claus Grøn Sørensen stresses that robots can help in supporting a sustainability and green transition. Secondly he argues that robots can replace repetitive work at the farm. Finally, **Claus Grøn Sørensen** argue that a concern could be – that we are missing to see that we are transforming the whole system – that could be a concern/impact. Therefore we need multidisciplinary development to make sure that all the implication for the whole farming system are considered and mitigated **(Claus Grøn Sørensen).**

Suzanne Baron mentions that one important impact will be in regard to economics and sustainability, where robots will help to make farming more sustainable. Secondly **Suzanne Baron** point out that another change is related to social impacts with benefits from reduced labour use. However, there will be some activities that are required in the transformation from conventional to robotic systems such as – a need for technicians to repair robots and provide additional services – it will also change the type of labour skills and activities that are needed when using robots compared with conventional systems. Finally it is pointed out by **Suzanne Baron** that environmental impact is also important. Robots will help to gain more benefits from conducting precision farming and site-specific application of inputs in the field and thereby safe inputs **(Suzanne Baron). Bertrand Pinel** argues that a first priority is a need for rules and laws in the area. Business is going too fast compared to the legislation. Secondly, there is according to **Bertrand Pinel** a need for advice about how to use the robots in the field. Finally he mention that it is a priority in regard to collection of big data and how to share and use them **(Bertrand Pinel).**

Orial Serra argues that the following issues are key priorities to him. Firstly, Social impact, secondly economic impact and finally political impact **(Oriol Serra).**
Michael Koutsiaras argues that it is firstly a priority to create business models for a large scale use of robots. Secondly, there is need to prove they (robots) are cost-beneficial and finally a third priority is to prove we have a positive impact on environment.

In addition it is mentioned that a concern is that robots may become too complicated. There are too many things to consider concerning sustainability and use of robots – and too many things must be taken into account **(Michael Koutsiaras).**

What do you suggest be done to minimize negative impacts and maximize positive impacts in the project implementation

In short, education, training and knowledge sharing are important to reduce negative impacts **(Ole Green).** To maximize the positive impact – it is important to make sure that the robots are reliable and the service that follows with the robot works properly **(Alea Scowill).**

In the Robs4crops project it is complicated and there is a risk that too many people are involved – challenging to ensure coordination between those in charge of the many parts. In terms of pilots, it now starts to get clearer who does what for the technical part. Communication with technical partners is crucial **(Michael Koutsiaras).**

In terms of users, there is a need for training and education, especially how to use it on the farm, how robots interacts with the rest of the production system. You need to put people together in social interactions to gain the benefits for the whole farm. The technology providers, they also need to be closely involved with the users for instance in living labs. In a first stage, focus should be on the collaboration between robots and humans **(Claus Grøn Sørensen).**

In short, education, training and knowledge sharing **(Ard Nieuwenhuizen & Fred Kool).** A challenge is the training of users and farmers. In addition some technical challenges also occur in regard to the use of robots on different soil-types and technical difficulties in regard to avoiding specific obstacles in the field. These safety issues may also create some challenges. But it is becoming easier to deal with these challenges with more training, service and introduction. Using robots as a Service (RAAS) with trained distributors can bring more economic benefit and less risks to the end-user **(Suzanne Baron).** It is also important to explain to farmers that it will reduce environmental impact and ensure that trials are made **(Oriol Serra).**

Who do you think will be affected by the project implementation?

Regarding farmers in general – there will be a change of mind with more management tasks etc. Advisors, they have to increase training activities, ag-tech providers they have to integrate designs to fit farming systems. Consumers, might change their perception of farming – and see it as a more industrialized system with robots **(Claus Grøn Sørensen).**

Alea Scowill argues that farmers will be affected for sure, consumers may also gain more transparency by using robots – because you can see what is happening from data collected by robots at the field. Consumers may also get better quality food from using robots**. Ole Green** argue that all members of the society, not only farmers, but everybody that buy foodwill be affected in regard to food safety, climate and traceability – it will imply that all members of society will be affected **(Ole Green).**

Farmers will be affected in a positive way because they can manage the farm at a distance – which gives them more time for other activities. The application of robots in agricultural practices can encourage the younger generation of farmers to take over farms **(Suzanne Baron).**

People working with tractors and business directors will also be able to reduce labour costs **(Oriol Serra).**

End users clearly will also be affected. The farmers will see what will be implemented in their farm and how to think of new technologies, maybe make them use the systems. Researchers will advance know-how. Companies will be helped to achieve their own ambitions for their own companies. **(Michael Koutsiaras).**

How do you expect introduction and increased deployment of farming robots to influence your role as (farm advisor/consultant, machinery dealer, robot manufacturer, contractor, research & experimentation)?

There will be more research on system integration, robots and the whole system approach. We have seen an increased number of papers on social- technology transition – within the last 5 years. That will also be the case in the future to integrate social and technical research **(Claus Grøn Sørensen).**

Ole Green expects that we as a manufacturer (Agrointelli) will get busier – we will have to do more scaling up activities. Basically, cost efficient scaling with the development of more cost-efficient solutions **(Ole Green).** We will learn a lot more about farmers from the data generated from using robots. We will also be more busy in developing robots **(Alea Scowill).**

In our company (Agreenculture), we will have to think more of robots as a fleet management system and a farm strategy. How to optimize several robots on a farm at the same time – we will have to optimize the time spent on the farm and the farm output **(Suzanne Baron).**

As a farm advisor an opportunity for showing create more work farm advisor about the robots **(Oriol Serra).** The Agricultural Adviser will not see a big change if the field work is done to a greater extent with machines. The plant breeding consultant has an understanding of and looks at weeds and makes field plans. Plans must be adapted to the equipment used by the farmer. It does not require a new type of plant breeding consultants. Advice on investment calculations for the acquisition and operation of robots also does not require a new type of financial advisors **(Rita Hørfarter).**

Research and experimentation: Mainly through the pilots we will be doing monitoring of experimentation. We will be able to better understand some aspects of robotics and Artificial intelligence **(Michael Koutsiaras).**

There is a major challenge with knowledge boundary between researcher and users – some farmers are using precision farming services. Precision farming application may be simple with crop monitoring etc. – Autonomous vehicles that are more advanced has not been applied much (In Greece). Robots are more complicated to use and require more knowledge **(Michael Koutsiaras).**

Who should control data produced and used by robotic farming systems?

Most of the stakeholders state that farmers should control the data. The one that produce the data should control the data, so in principle it should be the farmer – and then he/her should be able to delegate this information to others. That is also recommended in the EU code of conduct paper (EU Code of conduct on agricultural data sharing by contractual agreement) about data handling. You give permission on making contract with others to use the date for specific purposes **(Claus Grøn Sørensen).**

Ole Green argue further, In regard to management of data that we need someone (institutions ed.) to protect small units to be protected from larger players. We basicly need to control the large players. Some of the big players have too much power.In that sense, GDPR is to the benefit for small players – but it require some modifications to protect those who are intended to be protected. The problem is that we now basicly accept everything – for instance - you don't read all the text with small letters when you accept some conditions in an app or homepage – **Ole Green** gives an example with a standard kids toy (a small toy robot) – In this case you had to accept foto-sharing, sharing pictures, messages on your mobile unit when connecting your mobile phone with this piece of toy – otherwise the company did not allow you to use it – that is a crucial problem in my view **(Ole Green). Alea Scowill** also argue that manufactures can learn from the data but the ownership of the data should be among the farmers **(Alea Scowill).** The farmer can give us (manufactures) the rights to use the data for optimizing the use of robotics. The data produced by the robot is still to be discussed with the farmer. Currently it is the farmer that control the data **(Suzanne Baron). Bertrand Pinel** believes that both the farmers and cooperatives like Terrena in France should have control of data.

The farmer will probably think that it is ok for the manufacturer to get and utilize data from his use of the equipment to improve the robot, but the farmer will probably want to be able to decide to what extent the same data is available to eg the authorities. From a development and technology point of view, it is important that manufacturers have access to and can improve on the basis of data collected through the use of the equipment. The robots and their control system must be serviceable 24-7 and the workshop must be close by **(Mette Walter).** In general, farmers should own the data and be able to decide how to use them. Still, for farmers data is also a business opportunity **(Ard Nieuwenhuizen & Fred Kool).**

Other argue that the farm advisors could use the data – and other people who know how to use them. However the owner of robot has to take control of data **(Oriol Serra).** In Denmark, where 98% of the farms are members of the same agricultural organization and have confidence that data collected through this organization can be kept confidential and for the benefit of agriculture. Data is here used for consulting and model development. With GDPR, farmers have given permission for data to be used for advice to the individual farmer and / or for the development of common systems **(Rita Hørfarter).**

Farmer must be able to decide whether they want to share data with 3rd parties etc. Issues where companies provide services, and they sometimes use data for their own interest. The company will make profit by providing the service. These companies should not be able to reuse data without the farmer knowing about it **(Michael Koutsiaras).**

Similar arguments are made by **Sven Hermansen.** If a robot runs and collects data in a field, it is the farmer's or company's data. Data has value for the company, but the farmer must have a share in the gain or access to data. For the farmer, the ambition must be that data contributes to a better product for the benefit of the farmer himself and the rest of agriculture **(Sven Hermansen).**

A way to speed up confidence and use of robots: Robot manufacturers should not just focus on selling the robots, but also assist in using it. A three-month guarantee is not enough for the farmer. A pay per hectare payment and a compulsory service included in the contract could be a solution to that problem (**Han Hilbrands).**

Who do you think will have the capacity to analyze and exploit data collected by robots in a large scale?

The bigger the company is - the better capacity they have to collect data, so big companies may exploit the data – which is not necessarily to the benefit to the farmers. Legislation should be adapted to handle the data **(Alea Scowill).** Google, Microsoft and Apple are all companies that will have the capacity to exploit data - as examples **(Ole Green)**

Others argue that it could be an advisory company like e.g. SEGES in Denmark. It could also be the ag-tech developers and manufactures, they are using it for diagnostic purposes and improvement of the systems. Further up in the supply chain it may be used by intermediaries and food processors like Arla (Dairy company) in Denmark or other companies that have an agenda to reduce the climate impact **(Claus Grøn Sørensen).** Similar, cooperatives such as Terrena in France is collecting data using them for the benefit of members. They built a platform for protecting data, and take advantage. But also collaboration with John Deere for collecting data **(Bertrand Pinel).** Larger companies and advisor could make a contract to make the analysis so as to be used as a tool for the farm advisor **(Oriol Serra).** More specifically, cloud based system are available in the project –work is done on how to orchestrate a system adapted to Agricultural robots **(Ard Nieuwenhuizen & Fred Kool).**

At a larger scale, it might also be research institutions that have an interest. Advisors could also have an interest and capability to exploit the data to make yield estimations and other type of decision support **(Suzanne Baron).** Large companies – universities should have the ability. If they want to use the data for the greater good in a region/country, we must develop structures at state level for centralizing expertise in analysis and prediction. Public organizations should be able to do it. **(Michael Koutsiaras).**

How do you see the relationship between farmers and agricultural service providers as robotic solutions are introduced?

There have to be a larger integration between these two parties. In general, European farmers lack behind – because farming is often a family based business with small units. In Brazil and Argentina it is more like a business because of larger scales etc. It appears to be more professional as the primary farm activities are integrated with the whole food chain. E.g. the big feed producers are integrated in the entire food chain. In the US – the integration of the food chain is also more integrated –such as the company behind Kellogg's – they are buying farms to secure enough maize in the supply chain.

In Europe the integration is not as pronounced as in America – it is more family based, although we have cooperatives. Similar, in a country like India farms are very small and mainly producing for self-sufficiency – here the introduction of robots require another approach **(Ole Green).**

I don't think the current distribution, sales process, and servicing of robots versus tractors will change much. Farmers want to see the robots in action and experience them (sometimes several times) before they purchase. The process is similar to buying a car or house. But because there is more data being recorded, the robot companies have a good chance of being able to provide better maintenance and service **(Alea Scowill).**

A higher degree of dependencies between farmers and service providers are expected, farmers will be locked in with certain providers and that will create less freedom to the farmers **(Claus Grøn Sørensen).**

Farmers are often willing to test the systems and solutions that robotic service providers are presenting. There is in general a mutual trust between farmers and cooperatives – they are willing to test the robots within the cooperatives **(Suzanne Baron).**

The cooperatives can also play an important role when introducing robots – this is the case in for instance France. Usually it is not the farmer who owns the robot but a contractor – and it is often more financially efficient to rent it as a service instead of having your own robot instead of paying a new investment So the contractor will sign an agreement with the farmer to the task like mowing or other tasks at the farm. By doing so, farming operations have moved from the farmer to contractors. It works so far but that may change in the future – when more knowledge is gained among farmers **(Suzanne Baron).**

Michael Koutsiaras argues that the relationship is not always equal. Farmers are not aware of the way data are generated, managed, and used. In terms of knowledge relationship is not equal. I am not sure that companies will create transparency **(Michael Koutsiaras).** However it is also argued that there is common interest among both sites in selling products - it could be a win win situation **(Oriol Serra).**

Servicing the robots will set requirements for training and equipment at the workshop. For young / new mechanics there is no problem. They are already familiar with it **(Mette Walter)**

Mette Walter argues that the consultants have a long time to adapt to the new challenges. The dealers have taken over the task from machine consultants in the advisory service. It is otherwise an obvious task for the advisory service to investigate and be able to advise on how the machines can be used for various tasks and not weigh / re-examine how the field operation can be adapted to the robots / the new technology. The agricultural schools are fortunately far ahead with the use of robots / new technology **(Mette Walter).**

Other ethical concerns/impact in relation to the use of agricultural robots

Hopefully robots will make farming more attractive for a new type of farmers – maybe even create a more gender equal production system – it may for instance be attractive to those who or not interested in heavy machinery but also interested in food production. As such Robots could have an impact on the gender equality.

Robots will significant provide a positive impact on flora and fauna with more biodiversity. Robots will also enable us to conduct integrated farming – new methodologies for more biodiversity which is more cost-efficient than today. Instead of having 50 hectares with potatoes – a farmer could divide the field into small units – or maybe practice some fields with intercropping and multiple crops at the same field. Robots are not necessarily huge vehicles – and therefore we can design our farming systems with smaller management units. Then we may be able to increase biodiversity and reduce the application of pesticides with more precise operations **(Ole Green).**

Another argument is that robots may imply that we will lose some biodiversity because robots will standardize the way production is conducted. It may also be that the robots could be used to find areas that are not productive. There will be legal issues as well in regard to the safety of robots –

you cannot precisely find out what was the course of a certain mistake – whether it may be created by using the robot itself or by other. **(Claus Grøn Sørensen).**

Robots will also create new and different kinds of jobs – some people may be squeezed out with the new technology – but in my view they would lose their jobs anyhow – not just because of the robots **(Ole Green).**

Another ethical issue could be that EU or other authorities want to get access to data so that they can see what the farmers are doing. Hopefully the legislation will not create more control of the farms and farmers but instead help the farmers with better data **(Alea Scowill).**

We will see a greater distance between the farm we know today and farmers – and the intuitive feeling about how the crops and animals are doing. It is important that you incourage the development of small scale robots so that it will not only be to the benefit for large scale farming **(Claus Grøn Sørensen).**

Suzanne Baron argues that it depends on what the robot is doing – with only few sensors and data-handling as we see today – it probably doesn't bring many concerns.

We have an ethical committee in Agreenculture – their role is to think about those concerns – step by step. Currently, we are more concerned about the environmental impact. For instance by trying to reduce the CO_2 emission. The idea with the robot is to be more sustainable. However, at the moment there are only small ethical issues in my view **(Suzanne Baron).**

There will also be issues in regard to liability and theft **(Bertrand Pinel)** and issues about replacing the current labour, education and needs for the end-users – and the fact that farmers are aging **(Ard Nieuwenhuizen & Fred Kool).**

Some may be concerned about the prevalence of robots in general. Here, the widespread use of milking robots is a good example that there are certainly many benefits to the robots. The milking robots have not meant that there is significantly less to do in the cattle farm. These tasks are just different and less exhausting tasks to be solved **(Mette Walter).**

Current legislation and safety requirements may be a hindrance to proliferation. Should the robots be constantly under surveillance, not much has been gained from it. But the hassle of monitoring is probably a transitional problem that is solved when we gain increased confidence in the robots and not the least increased confidence in their control and monitoring systems **(Rita Hørfarter).**

A downside to increased use of robots in plant breeding may be that there is a further depopulation of agriculture. It will probably also affect the agricultural structure in a direction towards larger and larger farms. The follow-up industry and consulting must adapt to the new reality with the robots. There will be less need for old-fashioned tractor mechanics, now more focus is on software, sensors and operating systems. That development is already underway with the existing tractors and equipment **(Rita Hørfarter).**

In a later phase more robots in production could put pressure on communities to use robots. Also, reduction of labour costs – what happens to the workers? Are they reskilled and upskilled? Reskilling will be very important. Someone needs to understand how to handle the robots used for e.g., spraying and weeding **(Michael Koutsiaras).** In regard to ethics, issues about assurance is also relevant to consider **(Oriol Serra).** Ownership of data must be in order - or assurance that the product / technology is developed for the common good - and the companies do not sort in data to promote their own product on the wrong basis **(Sven Hermansen).**

It is also argued by **Sven Hermansen** that security and safety is a major challenge for the approval of robots. A country like Denmark is sluggish in this matter but security and safety requirements must be met – and it will probably be resolved. Robots are, after all, no more dangerous than stray animals.

Summary of non-farmer stakeholders' view on social impact

- A general perception among most of the non-farm stakeholders is that robots will provide environmental benefits.
- Robots will save labour hours in the field and reduce repetitive farm tasks and thereby be more convenient to farmers.
- Robots will change working routines on the farm and potentially move tasks from the field to the farm office and urban activities. Some concern is raised about disruption leaving some farmers behind as technology develops and change very fast.
- Robots are expected by most stakeholders to reduce negative environmental impact and enable a better use of precision farming and site-specific crop management, especially in regard to pesticides (herbicides) use of fertilizers and reduced soil compaction.
- Robots may also create some concerns about polarization among job-functions and disruption.
- It may also imply that some jobs will move from the rural areas to urban areas.
- Farmers will have to get used to new working routines.
- Robots will not necessarily create problems about data handling and ownership – but it is recommended that farmers are in control of data handling
- There are still a number of challenges to deal with in terms: reliability, safety, cost versus benefits and logistics for robots compared with conventional systems

5. Discussion and conclusion

This study has elicited potential social and environmental impacts of agricultural robots based on farmer surveys and interviews with non-farmer stakeholders. In the farm surveys, we collected information from several viewpoints:

- main challenges with conventional machinery use and farm management,
- priority features of agricultural robots sought by the farmers,
- expectations about the impact of agricultural robots on several indicators,
- motives to use agricultural robots, and
- concerns about agricultural robot

Analysis of the main challenges associated with the use of conventional machinery and farm management practices (high labour demand, soil compaction, inconvenience to transport machinery, lack of flexibility and compatibility, precision in estimating crop water and nutrient status, access to relevant technological solutions including Decision Support Systems (DSS) (28%) and relevant and timely information) indicates the need for accessible, light-weight, less labour-dependent and adaptable solutions integrated with relevant FMIS.

Analysis of farmers' concerns about agricultural robots sheds light about key social and environmental impacts such as safety, affordability and adaptability to small farm sizes, and to some extent data privacy and need for specialized knowledge. The fact that only 20 percent of the respondents found issues about data ownership to be a concern suggests that there is good reason to explicate the sort of concerns that data ownership may generate for farmers, since it does not seem to be "top of mind" for the surveyed farmers.

Moreover, the reported motives to use agricultural robots include incentive to reduce environmental impact through the primary driver appears to be increased profit. As observed from surveyed farmers' priority about features of agricultural robots, safety ranks as the third most important priority next to ability to perform under different weather conditions and capacity to work for long hours without reduced efficiency. The most direct form of questions are the ones related to farmers' expectations about the likely impact of agricultural robots on a list of economic, social and environmental indicators (results presented in section 3.2.1). The results show that farmers expect agricultural robots to result in a reduction of labour demand, exposure to tractor vibration, soil compaction, and chemical emission. While a reduction in labour demand can possibly be associated with economic gains for farmers (farm owners), this also arises a social concern in the form of diminishing employment opportunities for agricultural labour. On the other hand, reduction in worker exposure to tractor vibrations can be regarded as a desirable social impact of agricultural robots. As far as expected environmental impact is concerned, reduction in soil compaction and chemical emission are on top of farmers' expectations in our sample. Farmers' expectations about reduction in fuel, herbicides and seed also provide important messages. Alongside potential economic gains for farmers, these changes also would have important environmental and social implications in the form of improved health conditions and reduced emission, among others.

The results presented in this report should be regarded with some reservations due to a relatively small sample size and the fact that agricultural robot are new to society and therefore little information is available among farmers. Despite these limitations, the data provide important perspectives and useful insights.

To sum up, most of the farmers expect agricultural robots to save labour time and reduce the amount of fuel, herbicide, and seed. However they have also concerns about high investment costs compared with conventional equipment and concerns about safety and reliability aspects.

Based on the surveyed farmers' responses about their current challenges with conventional machinery and farm management as well as their expectations about the potential of agricultural robots, there appears to be a clear need to develop, provide and promote robotic solutions.

The non-farmer stakeholders appear to be more concerned about job polarization and loss of jobs, data ownership and privacy and further consolidation of farming.

In relation to the expected social impact of the four pilots, there seems to be some differences. The pilots in France and the Netherlands are expected to enable farmers to meet a lack in labour force, whereas in Spain and Greece there is a worry that the impact will be job loss. In the latter case this may require reskilling of laborers for other farm related jobs. There also seems to be a concern that the introduction of robots will be perceived as less attractive in Greece and Spain, perhaps due to the cultural identity of farmer communities. In these cases the social impact in terms of effect on farmers' conception of what it is to be a farmer may be more foundational. Finally, in Greece and Spain the pilots are expected to effect a change in the way farmers perceive of robot technology by showing what the technology can do for farming.

Combining the learnings from the farmer surveys and the non-farmer stakeholder interviews, a SWOT (Strength-Weakness-Opportunity-Threat) analysis has been made as presented in table 4.1.

Table 4.1. SWOT analysis for farming robots

Strength	Weakness
• Robots can do arduous and/or repetitive tasks on the farm • Give the farmer more time to farm - and time to consider what to do in the field and take notice about what happens on the farm • Able to integrate several intelligent tools for optimized benefit • Environmental benefits such as reduced application of crop protection chemicals, reduced soil compaction due to lower machinery weight and/or improved route planning, reduced emissions through energy efficiency improvements • Enable farmers practice precision farming in a better way • Enable farmers to work on tasks with more added value. This can be especially important for small and middle sized farms • Robots can be used for several operations	• Currently targeted for specific operations making it difficult to optimize the whole system • Limited capacity of the robots relative to cost • Technology is changing fast. This can make farmers skeptical to invest with the fear of the current technology being outdated/outpaced in a short while • Limitations to show the real net benefits for the farming system. Need more examples of cost benefit analysis • Need for physical monitoring under current legislation • Difficult to test robots on farm • Logistic challenge, e.g., to manage a fleet of small robots, transport robots from field to field • It is costly to train farmers to use robots • Not a quick fix to solving labour problem • Not suited to traditional growers

Opportunity	Threat
• Opportunity to be more sustainable (e.g., environment, working conditions, safety, traceability, improved use of water, nutrient and chemicals) • Advances in artificial intelligence (AI) and Internet of Things (IoT) and their improved integration with robots will enable robots to take more cognitive tasks • Increasing field demonstrations will bring farmers closer to the robots • Farmer involvement in co-design of the systems with existing tools helps improve relevance and reduce investment costs • New business opportunities, e.g., training, servicing robots • Robots generate versatile data that can be used to evaluate performance of applications and adjust strategies	• Job polarization, job concentration in urban areas and people moving from rural areas • Autonomous robots move the farmer from the direct farming activities to a more industrialized system, i.e., loss the farmer's touch of finger • Autonomous systems may harm people especially when humans work with more cognitive tasks alongside robots • Legislation: unforeseen new legislation against using robots, regulation changing so often • Ownership and control of data • Further depopulation of agriculture, consolidation, move towards larger and larger farm sizes • Cybersecurity and risk of hacking of systems • Lack of public acceptance, e.g., for reliability concerns

The major strengths are associated with labour savings and possibilities to optimize input application. On the other hand, the major weaknesses relate to low capacity relative to cost, unfavourable/underdeveloped regulation, limitation to adapt to several farming operations & farming systems.

Robots are expected to provide several opportunities such as improved sustainability and green transition of farming, co-design of solutions based on available tools which can improve relevance and also reduce investment cost to end-users, and new business opportunities such as training and robot servicing. However, many threats such as risk of moving the farmer away from what is traditionally farming, job polarization, data ownership, cyber security, legislation, etc. may stand on the way against widespread development and utilization of robotic solutions for farming.

Therefore, closer collaboration among stakeholders is needed to build on strengths, tackle challenges, take advantage of opportunities and devise mutually beneficial solutions to minimize undesirable impacts of potential threats.

Recommendations for further development

- Developers of robotic systems should carefully consider how the robots should be designed and applied. There appears to be a dilemma between developing a robot that is a tool carrier to handle all tasks – or a targeted systems for specific purposes like weeding or weed scouting tasks.
- To save money it could be relevant to apply existing tools that is mounted on the robot.

- There are obvious tasks for many / small robots with for instance weeding. But there is only a short time window for solving such tasks – this may create a logistic problem when handling many robots, this issue should also be considered when designing robotic systems.
- Data could be stored - for instance in five years, as documentation that precision assignment has been carried out and pressure on the ground has been reduced.
- Control of data should in principle be carried out by farmers but other stakeholders in the agri-supply chain may gain from data handling – if farmers give access to this data.
- Safety regulation is regarded as an important issue.
- Common Standards are needed for robots.
- There is a clear need for training and education among farmers and advisors for using robots.
- It should be clarified if consumers have any concerns in regard to food produced by robots.
- Farmers should be involved in the co-design of the systems with existing tools, which also helps to reduce their investment costs.

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7. Appendix

Survey questionnaire for social and environmental impact assessment (English Version)

October 2021

Dear participant,

This survey is prepared as part of a European Project called ROBS4CROPS (https://robs4crops.eu/) which intends to integrate and demonstrate robotic solutions for crop farming with a focus on two most demanding and repetitive crop farming operations, namely weeding and spraying.

The survey is intended to:

- get understanding of the state of robotics applications in agriculture,
- learn about the experiences, perceptions, expectations, concerns, and challenges of farmers,
- get useful insights into social and environmental effects of robotic farming

The purpose is to integrate farmers' views and needs into robotics design and implementation in order to provide practically useful solutions.

Your participation is greatly valued. Please be assured that the data will be used for the intended purpose only and your privacy is protected.

You can choose to answer anonymously.

Thank you in advance for taking the time to fill and return this questionnaire.

Kind Regards,

(Name of contact person from each pilot case site)

Bertrand or Charles from Terrana, France,
Michael or Spyros from AUA, Greece,
Fred Kool from Wageningen, Netherlands
Oriol or Raul Sànchez from Serrater, Spain

Participant Consent

Privacy disclaimer: your participation in the survey is voluntary; data will be treated anonymously and your privacy will always be guaranteed.

Do you agree that data you provided will be used for research outputs within the scope of the project? Mark with an X if you agree.

- ☐ Yes.

Do you agree that data you provided will be stored in a secured database according to EU rules and regulations? Mark with an X if you agree.

- ☐ Yes

Demographics and experience with farm management

1. Year of birth____

2. Gender
   - ☐ Male
   - ☐ Female

3. What is your education background?
   - ☐ Primary education
   - ☐ Secondary education
   - ☐ College education
   - ☐ Specialized agriculture training
   - ☐ Other. Please specify_______________

4. Country of your farming operation
   - ☐ Spain
   - ☐ France
   - ☐ Greece
   - ☐ The Netherlands

5. For how long have you been involved in farm management? Provide approximate number of years.

   __________________________years

6. Do you participate in field technology events such as workshops, trainings, conferences, agriculture-fairs, etc.?
   - ☐ Yes, often
   - ☐ Yes, occasionally
   - ☐ I have not considered of participating in such events
   - ☐ I would like to participate but never invited
   - ☐ No such events are organized in my region

Farm characteristics

7. What is the approximate total land area of your farm in hectares (including rented/leased land)?

   _________ha

8. What proportion of your total farm area was used to produce the crop categories provided in the table below? Put zero (0) for crops not produced on your farm during the respective periods.

Crop type	*Area planted/covered with crop during 2020/2021(ha)*	*Minimum farm area that you believe could be relevant for robotics applications (ha)*	*What is the average distance from the crop field to the farm office? (km)*
Vegetables			
Table grapes			
Vine grapes			
Apple orchard			
Potato			
Onions			
Pumpkins			
Other crops including grassland			

9. What is the total number of fields you operate on your farm (including rented/leased land)? ___

Machinery use and capacity

10. How many of the machineries listed below do you currently use including rented/leased/shared/contracted machinery? Please also provide the maximum capacity of the respective machinery and list the crops for which you used the machinery.

Machinery	Number of machinery used during the year 2020/21	Maximum capacity of machinery (working width in meters; horsepower in hp for tractors)	Number of repetitions for the specific operation in the field during a year (on average)	Crops for which machinery is used, please give a name for all crops
Tractor		__________hp		

Harvester		__________m		
Seeder/planter		__________m		
Weeder		__________m		
Sprayer		__________m		
Pruning machine		__________m		
Fertilizer applicator		__________m		

Human resource, labour challenges and time use

11. How many **field staff** do you employ (including yourself) on average per year during the last 5 years?

Staff type	Number of staff (on average per year)
Permanent full time staff	
Permanent part-time staff	
Temporary/seasonal labour	

12. How much time in hours per year do your staff (including yourself and temporary workers) use on field related activities on each of the following tasks?

Type of task	*Hours per year*
Office work (preparation of yield or application maps, learning new procedures)	
Learning time (e.g., training, attending workshops)	
Feld operation (outdoor activities)	
Finding, managing, and overseeing farm workers	

13. Do you have difficulties finding enough farm workers when needed?
    - ☐ No
    - ☐ Yes

Farm management challenges

14. What challenges do you currently experience in your field operations and management with field equipment? Choose as many as that applies to your case.
    - ☐ Precisely estimating crop water and nutrient status within the field
    - ☐ Access to relevant technological solutions (including decision support tools)
    - ☐ Affordability of available technological solutions
    - ☐ Complexity of available technological solutions
    - ☐ Cost of staff training to be able to use states of the art technologies
    - ☐ Access to relevant and timely information
    - ☐ Others. Please list your other challenges

      ____

      ____

15. What problems/challenges do you experience associated with the use of conventional (manned) farming machinery (excluding robots)? *Choose as many as that applies to you.*
    - ☐ Soil compaction due to heavy machinery
    - ☐ Lack of compatibility among machinery/implements from different suppliers
    - ☐ High demand for labour to operate the machineries and also perform tasks that cannot be handled by those machineries
    - ☐ Lack of flexibility to perform different operations
    - ☐ Inconvenience to transport from field to field
    - ☐ Other problems/challenges. Please specify
      ____

16. From the list above, which one is the most pressing challenge for you?

    ____

Robotic farming

17. Please mark your experience with and plan for future use of robotics solutions for the crop farming operations listed below. Choose all that applies. (mark with an "X")

Operation type	*Never tried*	*Tried in the past but stopped*	*Using currently*	*Future plan*		
				Plan to use	*Not considering*	*Will not use*
Seeding						
Weeding						
Fertilizing						
Spraying						
Pruning						
Harvesting						
Irrigation						
Other operations						

18. On what percentage of your total farm do you currently apply robotic crop farming? ____%

19. Do you apply robotics for one or more of the following field operations for each of the crops listed in the table below? *Mark with an X if you apply.*

	Seeding	*Weeding*	*Spraying*	*Other (please specify)*
Vegetables				
Table grapes				
Vine grapes				
Apple orchard				
Potato				
Onion				
Other crops				

20. How would you prefer to supply/access machinery and expertise for robotic farming? *Choose as many as that applies to you.*

- ☐ Buying own machinery and self-operating (includes regular employees)
- ☐ Buying own machinery and paying someone else to do the operation when needed
- ☐ Sharing machinery with others
- ☐ Leasing/renting machinery
- ☐ Paying a contractor with expertise and machinery
- ☐ I have no preference
- ☐ I am not interested in robotic farming

Expectations, concerns, challenges, and opportunities for robotic crop farming

21. How do you think the use of robotics in farming would affect the economic, social and/or environmental indicators listed in the table below? (*mark with an "X"*)

Indicator	***Increase***		***Decrease***		*I have no idea*
	Yes (mark with an X)	*Expected percentage increase (%)*	Yes (mark with an X)	*Expected percentage increase (%)*	
Crop yield					
Number of farming implements used					
Crop quality					
Gross margin					
Net profit					

Labour demand					
Optimal input application (e.g., seed, fertilizer, pesticides, insecticides)					
Worker safety (e.g. chemical exposure, injuries/deaths from tractor overturn)					
Worker exposure to tractor vibrations					
Resilience to external shocks (e.g., weather, policy, health pandemic, crop price volatility)					
Soil compaction					
Chemical emissions					
Ease of documentation to e.g., public authorities and others					

22. How do you think the use of robots will change total amount of each of the following inputs on your farm? (*Mark with an "X"). For each of the inputs listed, choose only either of the three options: 'increase', 'decrease' or 'no change'.*

Input	**Increase**	**Decrease**	**No change**
Fuel			
Nitrogen			
Phosphorus			
Potassium			
Other fertilizers			
Lime			
Herbicides			
Insecticides			
Fungicides			
Seed			
Growth Regulators			

23. For which of the following farming operations do you believe/expect robotics to have potential economic benefit on your farm? *Choose as many as that applies to you.*

- ☐ Seeding
- ☐ Seedbed preparation
- ☐ Weeding
- ☐ Spraying
- ☐ Harvesting
- ☐ Pruning
- ☐ Fertilizing
- ☐ Irrigation
- ☐ Other

24. Do you plan to invest in robots for your farm within the next 10 years?

☐ Yes ☐ No ☐ I do not know

25. If you answered Yes to question 24 above, why would you like to invest in robotics? *Choose all of the options that are relevant to your case.*

- ☐ The technology is fascinating
- ☐ Potential for increased profit
- ☐ To save labour costs
- ☐ To reduce environmental impact
- ☐ Need to replace existing machinery anyway
- ☐ Increase crop/product quality
- ☐ Other reasons. Please specify

____

26. What would you like robots to be in size compared to current tractors/combine harvesters?
    - ☐ Smaller
    - ☐ Same size
    - ☐ Larger
    - ☐ Don't know

27. What do you think would be a reasonable in-field speed for agricultural robots to make them economically attractive for your farm? Mark only 1 option with X for each field operation.

Type of field operation	1-2 km per hour	2-5 km per hour	5-10 km per hour	>10 km per hour	Same as conventional tractors	I have no idea
Seeding						
Soil cultivation						
Fertilizer distribution						
Spraying						
Weeding						
Harvest						
Pruning						

28. Would you prefer robots to be fuelled by (you can choose more than one option in the list):
    - ☐ Diesel
    - ☐ Electricity
    - ☐ Bio-diesel
    - ☐ Hydrogen fuel cell
    - ☐ Methanol fuel cell
    - ☐ A combination of above fuels
    - ☐ Other

29. What do you think the primary benefit will be from using robotics in crop farming?

    ____

30. What do you think the three most priority characteristics of agricultural robotics should be? Please mark your choices with numbers where 1 denotes the first most, 2 the second most, and 3 the third most priority characteristics.

- Capacity to perform well under different weather conditions
- Capacity to work long hours (ideally all day long) without reduced efficiency
- Flexibility to perform different kinds of operations as needed

- Capability to accommodate several attachments (e.g., tillage tools, seeders, sprayers)
- Ability to communicate with other machines
- Safety levels at least equal to that of conventional machinery
- Other. Please specify ______________________________

31. How would you prefer to monitor the robotic/autonomous systems on your farm? *Choose only one option.*

- ☐ From the farm office
- ☐ From a tablet/phone
- ☐ From another vehicle
- ☐ In the field
- ☐ No monitoring
- ☐ I have no idea
- ☐ Other solutions, please specify __________________

32. What minimum percentage reduction in human operating time (including maintenance and monitoring) would make robots attractive for you to use compared to conventional tractors?

- ☐ 0-25% reduction
- ☐ 25-50% reduction
- ☐ 50-75% reduction
- ☐ 75-100% reduction
- ☐ I have no idea

33. If you are required by law to physically monitor the robotic/autonomous systems on your farm, what distance between you and the robot would make it practically feasible for you to apply robotic farming? *Choose only one option.*

- ☐ 0-250 meters
- ☐ 250-500 meters
- ☐ Above 500 meters
- ☐ Other
- ☐ I have no idea

34. What concerns do you have about use of robots in farming? (*Choose all of the options that you think are relevant)*

- ☐ Labour market disruption by replacing human workers by autonomous robots
- ☐ Safety and/or reliability
- ☐ Need for specialized knowledge to operate and maintain robots
- ☐ Ownership and privacy of data collected by the robot
- ☐ Consumer acceptance of my crop (perceived crop quality) may decline
- ☐ Lost/reduced autonomy of farmer
- ☐ High investment cost relative to conventional technology
- ☐ Low driving speed of robots according to existing regulations and standards
- ☐ Adaptability to small farm sizes
- ☐ Other. Please specify
  - ______________________________________
  - _____________________________________

35. Do you think there is currently adequate information and advice on robotics applications in agriculture?

- ☐ Yes
- ☐ No
- ☐ Don't know

36. Who do you think will be the primary data processor for robotic systems related data collected on your farm in the future?

- ☐ Yourself
- ☐ Your employee
- ☐ Consultant
- ☐ Farm input/machinery dealer
- ☐ Other (specify) ___________________

37. What do you think could be improved for further development of robotic technology for agricultural uses?

____

____

Use of Farm Management Information Systems (FMIS)

Farm Management Information Systems (FMIS) are an integral part of modern day farm management. FMIS is defined as a a planned system of collecting, processing, storing, and disseminating data in a form needed to carry out farm-related operational functions (Sørensen et al., 2010).

38. Have you been using (or are you considering of using) any Farm Management Information Systems (FMIS) for your farm business? *Choose only one of the following options (mark with an X).*

- ☐ Never used
- ☐ Currently using
- ☐ Used in the past but stopped
- ☐ Expect to use in future
- ☐ Not considering of using in future

39. For each of the tasks/purposes listed in the table below, tell us if you apply the task (management practice), and whether you currently use (and/or plan to use in future) any FMIS for the task. *Mark with an X for all that applies.*

Task/purpose	Currently apply task or management practice	Use of FMIS	
		Currently use FMIS for the task	I plan to use FMIS for task in future
Soil management			
Irrigation optimization			
Seed optimization			
Fertilizer optimization			

Pruning/trimming			
Harvest timing optimization			
Pest monitoring and/or pesticide optimization			
Route planning			
Controlled traffic farming (using the same wheel tracks for different operations)			
Crop/product Pricing			
Yield mapping and/or monitoring			
Investment planning and/or decision			
Crop rotation planning			
Task priority setting and/or task management plan			
Documentation			
Overall farm business optimization			

40. What type of data is fed into your FMIS? *You can choose as many options as that apply to your case.*

- ☐ Weather data
- ☐ Input use data
- ☐ Yield and crop quality data
- ☐ Market (e.g., price) data
- ☐ Observation data
- ☐ Satellite data on crop status
- ☐ Sensors data
- ☐ Other data

Any questions/comments?

41. Lastly, if you have any comments/questions/concerns you would like to share with us, please write them in the space provided below.

Respondent contact information (*Optional*)

If you would like to share your contact information, we would appreciate it if you write in the fields provided below. Note that your contact information will never be used to identify/trace your identity.

Name: ______________________________________
E-mail address: ___________________________
Phone number with country code: _________________

Thank you, you are done!

Additional results from farmer surveys that could be of interest to other work packages in the project

Respondents were asked to choose from a list of possible modes of accessing robotic machinery (Q20) with the option of choosing more than one. The most frequently chosen modes of robotic machinery ownership/access are: sharing machinery with others (53%), buying own machinery and self-operating (45%), leasing/renting machinery (20%) and contracting (18%). Non-purchase options such as sharing and contracting were also found to be preferred mode of robotic machinery access in a case study from Germany (Spykman, Gabriel et al. 2021). This implies that partnering with and facilitating access through farmers' associations/cooperatives would be a promising approach to provide farmers with possibilities of sharing (including machinery, risk, information and learning).

Farmers' preferences with regard to the type of fuel, monitoring medium, monitoring distance, data processor, etc also provide useful inputs to the technical work packages in the project.

- **Power source for robot: electricity** (60%), **Hydrogen fuel cell** (23%), **bio-diesel** (13%), diesel (10%), methanol fuel cell (3%), **combination (33%)**, other (8%)
- **Monitoring medium**

Medium of monitoring (Q31)	Freq. (N=38)	**Percent**
From a tablet/phone	17	44.74
From a tablet/phone ; In the field	8	21.05
In the field	6	15.79
Farm office; tablet	3	7.89
I have no idea	2	5.26
No monitoring	1	2.63
Other solutions	1	2.63

- Monitoring distance

Distance for physical monitring of robot (Q33)	Freq. (N=38)	Percent
0-250 meters	9	23.68
250-500 meters	9	23.68
250-500 meters	4	10.53
Above 500 meters	14	36.84
I have no idea	5	13.16
Other	1	2.63

- Primary data processor: 81% Yourself/employee

- Reduction in human operating time to make robots economically attractive compared to conventional tractors

Range of reduction in human operating time	**Freq.**	**Percent (n=37)**
25-50%	13	35
0-25% reduction	7	19

I have no idea	6	16
50-75% reduction	5	14
0-25% reduction; 25-50% reduction	3	8
75-100% reduction	2	5
10-25% reduction	1	3

Overview of non-farmer stakeholder interview

List of interviews

Person to interview and company/institution	Role	E-mail address	Date of interview	Responsible for interview
Ole Green Professor AU, Founder , Agrointelli	Robot development and manufacturing	olg@agrointelli.com	21 January	SMP
Alea Scowill Strategic product manager Agrointelli	Robot development and manufacturing	als@agrointelli.com	20 January	SMP
Claus Grøn Sørensen Professor AU	Aarhus University , Expert in smart agriculture	claus.soerensen@ece.au.dk	20 January	SMP
Suzanne Baron Project financing coordinator A greenculture	Develops and produces autonomous systems for agribusiness	suzanne.baron@agreenculture.fr	24 January	SMP
Mette Walter Project Portfolio Manager - Field Trials Danish Technological institute	Testing Ag /field technology	mwa@teknologisk.dk	25 January	JEØ
Rita Hørfarter Special consultant SEGES Innovation	Advisory services, Danish farmers association	rih@seges.dk	25 January	JEØ
Han Hilbrands Doorgrond.dl Smart Agri Technology, Netherlands	Smart Agr solutions, Netherlands	hanhilbrands@smartagritechnology.com	20 January	JEØ
Christian Holst CEO, Johs. Mertz Dealer of agricultural equipment	Johs. Mertz, Denmark The company (Johs. Mertz) Dealer of all type of agricultural machinery in Denmark	christian.holst@mertz.dk	25 January	JEØ
Sven Hermansen Chief Advisor	Innovation Centre for Organic Farming	sher@icoel.dk	26 january	JEØ
Bertrand Pinel, project manager Terrena, farm association	Site-manager France	bpinel@terrena.fr	14 January	SHH
Michael Koutsiaras Research Associate AUA	Site-manager Greece	michaelgkoutsiaras@gmail.com		SHH
Ard Nieuwenhuizen Researcher WUR And **Fred Kool** Researcher	Site-manager Netherlands	ard.nieuwenhuizen@wur.nl fred.kool@wur.nl	18 January	SHH

Oriol Serra Apple producer – entire supply chain	Site-manager Spain	oserra@giropoma.com	25 January	SHH

SSH: Sune Hannibal Holm, SMP: Søren Marcus Pedersen JEØ: Jens Erik Ørum

Guiding questions

1. What are your concerns about robots in farming (social, labour use, economic, environmental, cultural, political, privacy of data, transparency of data handling?
2. How do you see the introduction of robots in R4C pilots in terms of:
    a. Strengths:
    b. Weaknesses:
    c. Threats:
    d. Opportunities:
3. What do you think would be the 3 most priority impacts/concerns from introducing robots in R4C?
4. What do you suggest be done to minimize negative impacts and maximize positive impacts in the project implementation in general? How these would be in the specific pilot case you are associated with?
5. Who do you think will be affected by the project implementation? How?
6. How do you expect introduction and increased deployment of farming robots to influence your role as …(farm advisor/consultant, machinery dealer, robot manufacturer, contractor, research & experimentation)?
7. Who should control data produced and used by robotic farming systems ?
8. Who do you think will have the capacity to analyze and exploit data collected by robots it at a large scale ?
9. How do you see the relationship between farmers and agricultural service providers as robotic solutions are introduced ?
10. Do you see other ethical concerns/impact in relation to the use of agricultural robots ?

NB: If the person is not involved in R4C then the above questions/answer could be replied in general terms