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Research paper

# 'Smart farming' in Ireland: A risk perception study with key governance actors

Áine Regan

*Teagasc Food Research Centre, Ashtown, Dublin, Ireland*

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ABSTRACT

As research and innovation around Smart Farming further advances, there is a need to consider the impact of these technologies including the socio-economic, behavioural and cultural issues that may arise from their adoption. The current study explores the perceived risks and benefits arising from the development of Smart Farming in Ireland and in particular focuses on the different interpretations ascribed to risk issues by different actors. Semi-structured interviews were carried out with 21 actors who through their professional positions have some level of responsibility for the growth of Smart Farming in Ireland. Although the participants in the current study were largely in agreement about the benefits presented by Smart Farming for Irish agriculture and society, they held different interpretations and opinions when discussing identified risks. The main concerns related to consumer rejection of technologies, inequitable distribution of risks and benefits within the farming community, adverse socio-economic impacts of increased farmer-technology interactions, and ethical threats presented by the collection and sharing of farmers' data. The current study reinforces how ambiguity can surround the discussion of risks as individuals form perceptions based on divergent value judgements. The findings reinforce the call for discourse-based management of risks and the embedding of frameworks such as Responsible Research and Innovation within Smart Farming.

## 1. Introduction

Technological innovations have had a disruptive impact on society and the economy; computers, internet, social media, smartphones, robotics, sensors and cloud-based processes have revolutionised how society organises itself and how individuals and groups make decisions and behave. The practice of farming and food production is not immune to this digital revolution and is forecast to undergo significant change in the coming years and decades (Bronson and Knezevic, 2016; Teagasc, 2016). The acceleration of Digital Agriculture is evident through the increased, albeit frequently uneven, adoption of digital technologies on farms including smart machines, sensors, robotics and cloud computing (Carolan, 2016; Poppe et al., 2015). Precision Agriculture practices have enabled farmers to use farm-level data on inter- and intra-field variability to inform more efficient decision-making (Kempenaar et al., 2016). Smart Farming is argued to further advance these practices by enabling the aggregation of individual farm data with data from other farms and/or other sources (e.g. historical data, weather data, market data, benchmarking data); in many cases, this process occurs in real-time. This data can inform decision-making at farm, industry, and policy levels and/or support the development of new products and services (Shepherd et al., 2018; Sykuta, 2016; Wolfert et al., 2017b). It is anticipated that Smart Farming will improve efficiency and productivity, support sustainability, further develop the agricultural sector, and ultimately contribute positively to farming and rural communities. However, there currently exists a dearth of knowledge regarding the social, economic, ethical and environmental impacts of Smart Farming. Good governance practices emphasise that decision makers have a responsibility to anticipate and account for the potential implications of research and innovation for society. As research and innovation around Smart Farming further advances, there is a pertinent need to identify the socio-economic and cultural issues that may arise from their adoption.

### 1.1. *Responsible research and innovation in smart farming*

One governance framework receiving significant attention at European level has been Responsible Research and Innovation (RRI). RRI emerged to reconcile our current global need for techno-scientific progress with the moral, social and ethical expectations and requirements of society as a whole (Stilgoe et al., 2014; Von Schomberg, 2013). RRI does not seek to prevent or hamper technology development or innovation, instead, it aims to ensure that the trajectory which innovation takes is conscious of and responsive to the concerns, needs and

*E-mail address:* aine.regan@teagasc.ie.

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expectations of society (Asveld et al., 2015). RRI is viewed as having four main dimensions or principles (Eastwood et al., 2017): *anticipation* of social, ethical, economic or environmental impacts; *inclusion* of all actors' views in decision-making; being *reflexive* of one's own assumptions and to consider how they may differ to others; and *responsiveness* – taking meaningful action in response to concerns and needs raised. RRI is a value-based framework and these four principles are envisioned to act as a common set of objectives to guide decision makers and governance actors (Bronson, 2018). Before any RRI exercise is undertaken, it is argued that a required pre-cursor is to ensure 'RRI readiness' – to confirm the suitability of existing conditions and the capacity of key actors to embed these four RRI principals in research and development projects or initiatives (Eastwood et al., 2017). Evidence suggests that RRI readiness is relatively low for digitisation in agriculture (Eastwood et al., 2017; Rose and Chilvers, 2018). This is of concern given that RRI has been described as particularly necessary for 'societally intricate technological trajectories' (Asveld et al., 2015). Smart Farming undoubtedly fits this description with the envisioned radical transformation of the agri-food sector (Rose and Chilvers, 2018; Teagasc, 2016), alongside the socio-economic issues which are likely to arise in the development and deployment of these technologies (Bronson, 2018; Carolan, 2016; Small, 2017). Technological innovations have long been met in society with a critical spirit and often are accompanied by a public debate comprised of polarised arguments (Bruce, 2002). Not everyone will share the same vision and values when it comes to technological development and there is a need to identify and understand those issues which are likely to be most divisive or raise significant concern amongst key audiences. Alerting the research and innovation ecosystem to specific areas of potential conflict will not only allow for more targeted interventions, it will also further legitimise the call for RRI to be embedded within Smart Farming research and innovation so as to avoid alienation of any actors, potential polarisation and a technological impasse.

### 1.2. Exploring the perceived risks and benefits of smart farming

The benefits of digital technologies for agriculture are manifold: increased productivity and profit is promised for farmers (Bronson and Knezevic, 2016; Ge and Bogaardt, 2015) while at societal level, these technologies can help to tackle issues such as food security and sustainability (Carolan, 2016). At the same time, the disruptive nature of digitisation implies that social change is inevitable; markets, business models and value chains, farming and rural communities, ownership and privacy will all be impacted. These impacts can certainly be positive; but as with all scenarios where new technologies are introduced into society, there is also the potential for unanticipated adverse consequences (Bronson, 2018). Research has already pointed to specific areas of potential contention or concern: further amplification of the digital divide and inequitable development across different farms (e.g. small and big), regions (e.g. urban and rural) and individuals (e.g. age, socio-economic or education disparities) (Fleming et al., 2018a,b); technological unemployment and knock-on effects on rural communities (Bronson, 2018); and power imbalances particularly stemming from data ownership and sharing (Jakku et al., 2019; Shepherd et al., 2018). While previous literature tells us quite a bit about the types of risks which could arise with the introduction of Smart Farming, the current paper focuses specifically on how, and the extent to which actors may differ in their interpretations of these risks.

Within the field of risk governance, approaches taken to assess the risks of new technologies or radical innovations have previously attempted to categorise different risk situations (Renn, 2008; Renn et al., 2011). This categorisation stems from the initial premise that new or disruptive technologies are typically introduced in the context of limited or controversial knowledge as to the potential risks involved. It is argued that three types of risk knowledge environments exist. *Complexity* reflects the difficulty in establishing quantitative cause and effect where multiple variables are at play; *scientific uncertainty* exists where there is limited or absent knowledge; and *socio-political ambiguity* occurs in the presence of divergent value judgements (Renn and Klinke, 2014). While complexity and scientific uncertainty can be largely remedied by the collection of additional data and information, increased knowledge does not necessarily reduce ambiguity. Ambiguity reflects a risk environment characterised by different interpretations and meanings accorded to the same risk (Renn and Klinke, 2014). Risk perception plays a key role in defining an ambiguous risk issue. A significant volume of research carried out by social and behavioural scientists over the last few decades has established that risk is a phenomenon which originates in the human mind and which is influenced by subjective beliefs, values and social and cultural settings (McComas, 2006; Renn, 2005). The area of Smart Farming involves diverse actors: agribusiness, tech companies, venture capitalists, new start-ups, public institutions, universities, governmental organisations, farmers, consumers and civil society (Kamilaris et al., 2017; Wolfert et al., 2017b). These actors will evaluate technological transitions and developments in the context of their own experiences and values, and cognitive and emotive reasoning will be used to form opinions accordingly and to determine the risks present (Munnichs, 2004). Understanding risk as a social, cultural and psychological phenomenon reminds us that these different actors will inevitably hold different views and expectations about the development of Smart Farming, and areas of concern are likely to differ depending on whose viewpoint is sought (Hoes and Ge, 2017). In Ireland, Smart Farming is at a relatively early stage of development. The future direction of Smart Farming research and innovation in Ireland will be immediately determined by those actors in key positions of decision-making and governance, therefore it is of interest to explore how they currently perceive the risks and benefits of Smart Farming for the Irish agricultural sector and society more broadly. A particular focus for the current study is to explore actors' different interpretations so to identify the level of ambiguity surrounding different risks and benefits.

## 2. Materials and methods

### 2.1. Study context: smart farming in Ireland

A recent Technology Foresight report carried out in Ireland views the Irish agri-food sector – the most important indigenous sector in Ireland – as being on the verge of a technology-driven revolution with significant change forecast for the coming decades (Teagasc, 2016). While there is currently no strategy dedicated specifically to Digital Agricultural in Ireland, digitisation has been identified as a key strategic development for Ireland's agricultural sector. Development of Smart Farming in Ireland is supported by the national strategy for the Irish agri-food sector, *FoodWise 2025*, which views innovation as a primary requirement to increase the resilience of the sector. The *National Research Prioritisation Exercise* has also identified ICT as a research priority theme and it explicitly calls for the application of technologies to support the productivity and sustainability of the agri-food sector. The themes identified under this exercise correspond with the majority of competitively awarded public investment in research in Ireland. Accordingly, agri-food, science and enterprise research funders in Ireland have recognised digitisation as a key priority area to be addressed in funding calls and are increasingly seeking to fund collaborative projects operating at the interface between information and communications technology (ICT) and agriculture and food. Along with interdisciplinary research, publicly-funded research institutes are also increasingly working with the agri-food industry and ICT industry.

Tech development has been prominent in Ireland in recent years with several key tech companies such as Amazon, Cisco, IBM, Google, Facebook and Twitter locating their European headquarters in Ireland. The Irish AgTech start-up community has also grown rapidly in recent years – boosted by a number of government-led initiatives and the arrival of several AgTech-specific investment partners to Ireland.

Enterprise Ireland – the Irish state's economic development agency – views AgTech as a sector with particularly strong growth opportunities in Ireland (Enterprise Ireland, 2018). In the last two years, the agency has launched a €500,000 Competitive Start Fund specifically aimed at the AgTech sector and has hosted an 'Innovation Arena' for award-winning AgTech start-ups to showcase their innovations at the National Ploughing Championships – an annual national agricultural event which draws in a crowd in excess of 300,000. TechIreland (2018), an annual report of tech developments in Ireland, pinpointed 2017 as a significant year for the AgTech sector with the arrival of several funds and accelerators specifically targeting AgTech start-ups including Alltech's Pearse Lyons Accelerator; Finistere Ventures' Ireland AgTech Fund; The Yield Lab and SVG Partners' Thrive AgTech Accelerator. In comparison to the significant efforts to advance Digital Agriculture in Ireland from a technological and economic perspective, there has been relatively less research in an Irish-specific context looking at Smart Farming from a social and behavioural perspective.

### 2.2. Sample and data collection

A qualitative research design was employed and one-to-one, in-depth semi-structured interviews were carried out with key decision makers and governance actors. The selection of key informants was informed by a framework developed by Devaney and Henchion (2018). Under this framework, potential participants are selected based on an expert continuum which distinguishes three types of groupings of individuals based on their 'closeness' to the topic under consideration (Smart Farming): subjective, mandated and objective. Subjective closeness is defined as actors who have direct experience of Smart Farming, for example, industry actors and farming representatives; they can provide experiential knowledge of the topic. Mandated closeness reflects actors who have a professional role responsibility related to Smart Farming, for example policy makers, regulators and support agencies; they are able to provide strategic insight. Objective closeness reflects actors who explore Smart Farming from an unbiased and rigour-driven perspective; for example, scientists. Adopting a framework such as this ensures that a range of participants with different backgrounds are interviewed resulting in a rounded and inclusive reflection of opinions. Based on this selection framework, potential participants were identified through a general scoping of the Irish agricultural sector. Participants were required to have a high level of engagement with and strategic knowledge of Smart Farming; this was determined in advance of participant selection by examining prospective participants' areas of work (published papers, talks given, commercial activities, etc.). Purposeful sampling was employed to ensure representation of participants from each of the three categories. Following the completion of 21 interviews, it was decided to end the recruitment process. Richness and volume of data were guiding considerations in making this decision (Vasileiou et al., 2018). It was felt that the focused nature of the study, the amount of data collected, the depth of the data collected, and the diversity in the sample interviewed was sufficient to allow an in-depth analysis. All interviewees held senior positions and/or were the key contact point in their organisation for issues related to digital agriculture. The sample consisted of 6 females and 15 males and the interviewees were geographically dispersed across the Republic of Ireland. Interviews were conducted face-to-face with participants in a location convenient to the interviewee, generally their place of work. The interviews took between 50 and 70 min and were carried out during April-June 2018. Table 1 shows the break-down of participants across the expert continuum framework.

An interview schedule was used to structure and guide the interview. Questions were formulated to (1) explore participants' understanding of the term 'Smart Farming', (2) identify challenges and opportunities facing Smart Farming in Ireland, (3) explore perceived risks and benefits of Smart Farming in Ireland, and (4) identify future actions required in the further development of Smart Farming in Ireland. The anonymous and confidential nature of the interview was explained to participants at the start of the interview and interviewees were asked to sign a consent form. The research interview began with participants being asked to describe their interpretation of the term *Smart Farming*. They were then presented with a written definition and an image depicting a 'smart farm of the future' (including technologies such as survey drones, a fleet of agribots, smart tractors, 'texting cows', and farming data). Participants were asked to 'think aloud' as they viewed these materials and discuss whether they agreed or disagreed with them. These visual aids were used to further stimulate discussion around the characteristics which define Smart Farming from the participant's perspective. The subsequent discussion revolved around identifying strengths, weaknesses, challenges, and opportunities for Smart Farming in Ireland; exploring perceived benefits and risks introduced by Smart Farming; and probing participants' thoughts on next steps for the future development of Smart Farming in Ireland.

**Table 1**
Categorisation of Interviewees.

| Category of Expert Actor | *n* |
|---|---|
| *Subjective* | |
| AgTech Industry | 4 |
| Farming Representative | 2 |
| *Mandated* | |
| Government / Policy | 2 |
| Support Agency | 2 |
| *Objective* | |
| Social Scientist | 3 |
| Computer Scientist | 3 |
| Agricultural / Food Scientist | 5 |
| Total | 21 |

### 2.3. Qualitative analysis

All interviews were audio-recorded, with one exception at the request of one interviewee; instead written notes were taken during and immediately after this interview. The audio recordings from the remaining 20 interviews were transcribed verbatim. All data then underwent a qualitative analysis. Following good practice guidelines, a hybrid thematic analysis combining deductive and inductive coding was carried out (Braun and Clarke, 2006; Fereday and Muir-Cochrane, 2006). Active reading and re-reading of the transcripts took place to become familiar with the data. Using a deductive approach, two hierarchical codes "perceived risks" and "perceived benefits" were identified a priori. Hybrid coding was then undertaken specifically looking for discussion amongst the participants of the risks and the benefits of Smart Farming. The data was coded under a number of risks and benefits identified from the literature (social impacts, economic impacts, data concerns, digital divide, and power imbalances) but coding also sought to identify additional risks and benefits as presented in the data. Further inductive coding was then carried out to examine in-depth the manner in which these risks and benefits were discussed amongst participants and the different perspectives offered; this coding was grounded in the data. Data-driven codes were merged with theory-driven codes to develop themes (Fereday and Muir-Cochrane, 2006). The themes were then described, refined and named. Data extracts in the form of verbatim quotes were included to provide illustrative evidence of the theme: quotes were selected based on their vividness and ability to capture the essence of the point being demonstrated within each theme (Braun and Clarke, 2006). A thematic map was developed to aid interpretation of the findings (Fig. 1). QSR NVivo 10 was used to organise the data.

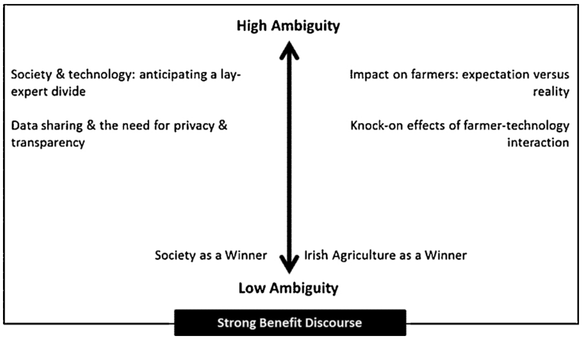


**Fig. 1.** Thematic map reflecting the identified risks and benefits of Smart Farming and the level of ambiguity apparent in participants' views.

## 3. Results

The current analysis aimed to (1) identify the perceived risks and benefits of Smart Farming in the context of Irish agriculture, and (2) explore different interpretations of risk and benefit issues across different actors, with a particular focus on understanding the level of ambiguity surrounding identified risk issues. Identified risks and benefits largely mirrored those currently observed in the wider literature, although some context-specific observations were evident. Identified as a recurrent theme across interviews, a strong benefit discourse was apparent throughout the dataset. While levels of optimism and enthusiasm varied across the participants, all participants acknowledged benefits brought about by increased digitisation in agriculture. In the accompanying thematic map in Fig. 1, this strong benefit discourse is reflected as an over-arching theme. Also shown in the thematic map are those themes reflecting the risks identified and how they were discussed by participants: *Society and technology: anticipating a lay-expert divide; Impact on farmers: expectation versus reality*; *Knock-on effects of farmer-technology interaction*; and *Data sharing and the need for privacy and transparency*. In the thematic map, risks and benefits are mapped by the level of ambiguity observed across the dataset. Low ambiguity describes those risks and benefits discussed by participants where participants largely echoed similar sentiments. In contrast, high ambiguity describes those risks and benefits which gave rise to different interpretations by participants. The map paints a striking visual of the high level of agreement amongst participants on the benefits of Smart Farming and the high level of ambiguity which surrounded discussion of the risks.

As an over-arching theme, a strong benefit discourse became apparent during analysis. All participants identified benefits of Smart Farming for Irish agriculture with positive knock-on effects for a range of different actors at farm level, at industry level, at policy level and at societal level. The Irish agri-food sector was viewed as being particularly well-placed to capitalise on Smart Farming developments. A number of participants identified opportunities specific to attributes of Irish farming including for example, the development of technology for pasture-based systems and sustainable expansion of the dairy sector. Participants also perceived significant value in digital technologies for evidence-based, data-driven policy-making to support the agri-food sector. The increased availability of farm-level data amassed from digital technologies was viewed as an opportunity to use evidence-based claims to market a positive image of the Irish agri-food sector and Irish produce.

*"At industry level you have a whole plethora of data that can be used to do different things, so genetic evaluations, whether that's grass or animal, sustainability assessment… there's a whole range of different things we can do by amalgamating data from different sources. So that means we can definitely put numbers around Irish product, which is very beneficial; it has marketing implications."* – Agricultural / Food Scientist 4

The further development of the AgTech industry in Ireland was viewed in a positive light by many. The strong existing agricultural tradition and the strength and position of the agri-food sector within Ireland were viewed as advantageous for the growth of Smart Farming in Ireland. Furthermore, the existing presence of large multinational tech industry in Ireland alongside a sizeable AgTech start-up community was viewed as positive for cultivating further growth and collaboration. With these aspects considered, there was a sense that Ireland could develop a strong national identity in AgTech. Growth of the AgTech industry was viewed as beneficial for the Irish economy more broadly, for example through the creation of new high-skilled jobs, many in rural areas:

*"It fits beautifully with the digital economy and with CAP for rural jobs, like these are skilled jobs that can be created… sensors won't cut it on their own - you need people that are interpreting information, that are redirecting it, that are understanding it…if any of the sensors are calibrated wrong their information is wrong, so I see high value jobs in rural economies."* – AgTech Industry 2

### *3.1. Society and technology: anticipation of a lay-expert divide*

Strong beliefs existed amongst participants that Smart Farming presented benefits for consumers and society more broadly. Participants were agreed that digital technologies are necessary to combat pressing societal issues. These technologies would enable more efficient farming practices therefore leading to more sustainable, safer and traceable food production and they were also viewed as a way to meet changing consumer demands (e.g. increased protein, cheaper produce). Participants noted that while all of society will benefit from the advancements of Smart Farming, consumers specifically can benefit from digital technologies as a result of the improved information flows and transparency introduced into value chains. Therefore, Smart Farming was viewed as something which could significantly empower and engage consumers:

*"The connection between people and where their food is coming from is important and I think these technologies could be a way to foster that. So you could use those barcodes to swipe milk and that could tell you where your milk is produced. It could be a way to improve trust and shorten connections between people and where their food comes from as well. It could be really positive."* – Social Scientist 1

Generally, Smart Farming as an overarching strategic development for agriculture was not viewed as contentious. Most participants were in agreement that society and consumers would benefit from a digitised agricultural sector. However, not all participants believed that consumers themselves would agree with them on this point. A 'lay-expert' perception gap was judged a possible risk with respect to Smart Farming technologies. While participants viewed positive outcomes for consumers from Smart Farming, there was a belief amongst some that they must also be prepared for the possibility of community opposition and consumer rejection. These participants, who spanned the three categories of experts interviewed, were reflective in their assessment of how others' may react and respond to technological development. This caution seemed to stem in part from an acknowledgement of past societal disquiet brought about by technological developments, including for example rejection of genetically modified foods and the 'Nimbyism' movement. These participants felt that societal acceptance of Smart Farming should not be broadly assumed but rather considered on a technology-by-technology basis. In considering individual technologies, genetics in particular was identified as an important technological subset of Smart Farming by a number of participants and one associated with significant on-going consumer resistance. Similarly, technologies which were viewed intrusive to a community, such as drones, could be met with resistance:

*"There's very few of those technologies outside genetics that would*

*impact consumers. I think most consumers wouldn't concern themselves with it. At the moment the idea the smart famer is presenting is one of the application of technology to the management of the farm. But that's only one small component. So you've got to bring into it genetics which is a big component of smart farming. And that's where you'll get kick back from the consumer I think."* - Computer Scientist 1

*"We can see that satellite broadband is taking off in a big way as well. What happens if there's a grant there for farmers like there is with solar farming, to have an actual base station there. Will your neighbours object to you putting this structure next to them? Which is always the same regardless of what technology it is: whether its telephone poles going up in the turn of the 1900s…. you're always going to have some form of reluctance and agitation about particular technologies… drones will be an issue, because it's more invasive than maybe other technologies which are within the farm boundaries let's say.* – Farming Representative 1

Not all participants mentioned the possibility of societal rejection; however, those who did were largely in agreement that the potential strongly exists for consumers and civil society to have different interpretations of the risks introduced by Smart Farming technologies.

### 3.2. Impact on farmers: expectation versus reality

In principle, all participants viewed Smart Farming as a positive development for farmers. Many viewed Smart Farming in its most basic description as the use of technology to help farmers make more informed decisions. Improved decision-making was viewed to enable efficiencies on the farm which would lead to several direct benefits for farmers including improved profitability through reduced costs and maximised outputs. Many participants also mentioned benefits for the farmer resulting from more efficient time management including a better work-life balance and enhanced quality of life. The enhanced work-life balance was particularly important for a number of participants because of the knock-on effects – taking away burdensome jobs and improving time management leads to benefits for farm safety, general well-being and mental health. Participants felt that Smart Farming technologies would allow for more efficient farm management, less paperwork and fewer time-consuming administrative tasks which would allow farmers to pursue and make time for other values and priorities in their life. There was also a sentiment amongst some participants that digital technologies could de-stigmatise the 'hard labour' culture and image in farming and help shape it as a more attractive occupation for new entrants:

*"It's interesting to see the stories that a farmer will talk about. So sometimes you might say, 'the number one benefit - surely it's economic, oh he makes so much extra per year'. Yea, that definitely comes into account. But actually it might be that he can be in earlier in the evenings to spend time with his family. Or actually, you know everything just operates a bit slicker. And it can be these softer things."* – AgTech Industry 3

*"I'd like to think that one of the benefits will be improved quality of life for farmers. That it will remove some of the labour intensive activities… maybe a reduction in their working hours. A reduction in the brute force that's required for so many agricultural activities."* – Social Scientist 2

While participants expected that in principle Smart Farming should deliver these benefits for farmers, reservations were evident in the dataset. Specifically, a number of participants questioned (1) the extent to which benefits would materialise in practice for farmers investing in technologies, and (2) whether benefits may be disproportionately distributed across the farming population. Most participants made reference to a significant financial risk incurred by farmers given the current high expense involved in purchasing and implementing these technologies. The promise of financial return may not always be guaranteed, or may only come after a lengthy period of time. There was a concern that some farmers may be too quick to invest in new technologies without first understanding their true value and application for their farm. A number of participants made reference to the need to critically reflect on the return in investment from individual technologies to ensure there is an end benefit for the farmer. A further concern amongst participants was that although these technologies are supposed to be labour-saving and time-saving, this is not always the case, and particularly initially as farmers get to grips with new technology – one problem cited was poor user design and poor user interfaces.

*"The biggest threat for me is the technology is adopted and it doesn't work or it doesn't give benefit…in that scenario, I think the only winner is the company that produces the technology… For me the big loser is the farmer that puts in a technology and doesn't use it and if you look at the literature a lot of these situations are the farmer doesn't use the technology after they put it in. That's not a good place to be… It's very important that the investment gives a return."* - Agricultural / Food Scientist 2

These concerns were a particularly strong theme amongst the 'objective expert' category (scientists). They strongly indicated that for farmers to invest wisely in technologies and reap the promised benefits (both financial and time-saving), it would first need to be shown and demonstrated that the technologies do actually provide a return on their investment and would work well in the context of individual Irish farms. In this regard, some participants pointed to the important role of consistent, evidence-based information and advice from independent and reliable sources – including advisors, independent organisations, scientists or peers. Some suggested the need for technologies to be tested and benefits proven in situ within demonstration farms, through discussion groups or through impact analysis studies:

*"Some of this area is developing relatively fast, what we need to do is to validate that the technologies that they're using underneath a Smart Farming system are appropriate for our production systems, our climate, our crop types and so on. It's down to really what is I suppose validation research, in other words it's either in research centres or going out to farms to quantify what benefit is coming from this because at the end of the day, you know, the technology has to bring benefit."* – Agricultural / Food Scientist 1

*"Right now and for the foreseeable future, farmers are being assailed from all angles by people selling them things. A new sensor, a new drone, a new something or other that will be good for you. And the temptation is always to buy something you know. If it's a new bit of equipment a lot of farmers love new tractors, or new bits of machinery, or whatever. Buying it before you know well do I have a need for it? And if I have a need, do I understand that need. And is this the right piece of equipment, or the right toy to help me to meet that need."* – Agricultural / Food Scientist 4

At the same time, a number of participants, particularly those coming from an AgTech industry background, took a slightly different interpretation of this risk issue. They voiced their opinion that in order for companies to succeed, end value to the farmer had to be ensured as it was essentially poor business practice to go to market with a technology that would not prove its worth to farmers:

*"Our focus is all on the farmer because he's our customer. He's the guy that ends up paying our bill at the end of the day and that's how, as a business you keep going and you keep growing. So we're very clear that the benefit has to be for the farmer. Because if he doesn't get a benefit out of doing something then the next guy won't adopt."* - AgTech Industry 3

A particular concern amongst a number of participants was whether the benefits of Smart Farming may be unequally distributed across different types of farmers. Many Smart Farming technologies were viewed to be prohibitively expensive and out of the reach of many farmers. There was a sense that only a number of elite farmers would be in a position to invest in these technologies, although there was an acceptance that over time some of these technologies would inevitably become cheaper:

*"This technology is not cheap. So the ability to make a capital investment of a sizeable amount is only available to a handful of farmers. So that's going to be the big barrier. A lot of this technology is about incremental improvements in margins. If your margin is relatively very low already an incremental improvement on a low margin is not much of a driver to adoption really. There isn't the economic driver for a lot of farmers to make these investments, not for smaller farmers; for more profitable farmers especially in the dairy industry then yes."* - Computer Scientist 1

A number of participants feared that certain farmers would be excluded from Smart Farming and could end up being marginalised within Irish agriculture down the line. Particular reference was made in the current study to older farmers and smaller farmers, who make up the current majority of Irish farmers, but who may not have the skills, capabilities, money or motivation required to capitalise on digital technologies. There was some future-visioning over how technology could end up leading to an over-emphasis on production and yields and detract from more traditional ways of farming. This was viewed as a risk to the livelihoods of many current farmers but also a risk to the public image that is portrayed of Irish farming. Participants urged careful consideration of how Smart Farming is developed to maintain the traditional culture and image of Irish farming, whilst also making optimal use of technologies:

*"I think one of the dangers with this is that a lot of these things promote scale. And data works best at scale. In some ways there's probably a tension between that and the picture of the nice little farm and it's all very natural and green I think there's a version of smart farming that promotes that and says well isn't it great that you can still do this but a sprinkling of technology here means you can bring in some of the optimisation that you get in these big industrialised farms. That's one version. The other version is that well yeah by bringing in all this technology you massively optimise everything and it becomes this big food factory."* - Computer Scientist 2

*"I think this is where there's a real need to first of all envision what you want to do, have some key policy objectives. So with smart farming we don't necessarily want less jobs in farming, we want rural and regional development where you have similar number of farmers, maybe being able to work in a smarter fashion with a higher quality of life, higher food safety and quality. But not necessarily, you know taking away the good elements of farming, and you know we want to build on some of the strong elements that the market is interested in, such as grass based production systems. So we need to I suppose set out what's the good things at the start. And the things we don't want to lose."* – Policy / Government 1

Not everyone agreed with the argument that small farms would be excluded from Smart Farming. Some felt that it was too simplistic an argument to say that Smart Farming is only applicable at scale. For these participants, Smart Farming was viewed as a concept and the technologies which fall under this concept exist on a continuum, and while some technologies are best used at scale, these participants were of the view that plenty of digital technologies can also help small farmers. The point was also made that some of the more expensive technologies could also be rolled out through business models which would make them accessible to smaller farmers, for example through third party service providers, through co-ops or used by government at national level to support farmers:

*"I think it's too simplistic to say small or big farms benefit, there's definitely technologies which help scale, and are only affordable at scale. But on the other hand there's also technology that can allow the small holder to thrive. Talking about can you connect to a consumer base, you know I have a small farm I'm going to go all organic, I'm going to reach out via Facebook… That's a technology enabling solution for a small farmer that didn't exist ten years ago. Large-scale technologies actually might still be available to a small holder farmer if it's done in a collective manner - by a co-op or even the national government. I don't agree that the technologies lend themselves just to larger farming or to further increase intensification. That's almost a 20*th *century mind-set of looking at things."* – AgTech Industry 4

### 3.3. Knock-on effects of farmer-technology interaction

Participants discussed increased technology use and reliance by farmers and the knock-on consequences which this may have for farms and for society more broadly. They reflected on the relationship and interactions that humans have with technology and the extent to which this relationship can be negative or positive. For some participants, while they appreciated that the introduction of digital technologies to assist in decision-making on the farm can be positive, they were concerned with the ripple effect that widespread adoption could cause down the line. Again engaging in future visioning, participants foresaw possible negative unintended consequences as a result of an over-reliance on technology. For example, a number of participants raised concerns' that the introduction of certain technologies could lead to changed behavioural patterns on the farm and the potential distancing and isolation of farmers both from their animals and from their community. This was viewed to introduce a number of different risks for the health and welfare of both farmers and animals.

*"I mean if you look down the future you can see the idea of farms increasingly being depopulated. There are fewer and fewer humans needed. Certainly this technology could lead you toward almost people free farms. And animals that don't interact with people. That's potentially a big worry for both animal health and the social and cultural dimensions of the landscape."* - Computer Scientist 3

*"Change can be very traumatic. It's not always positive. Farming can be a very lonely occupation now. And one of the effects of technology has been to make that worse. Okay we're living in a more connected world. But it doesn't mean we connect on a human level, with other human beings. It's all moderated, mediated through a machine. That is a major problem lurking there in the future - isolation and the lack of social interaction and opportunities."* – Social Scientist 2

Particular concern was expressed over an envisioned future smart farm whereby over-reliance on technology would impair farmers' ability to think intuitively; smart technologies were viewed to change the nature of decision-making away from the inherent skills and heuristics that farmers pride themselves on having:

*"Often these technologies can replace 'good farming'… they can replace skills that farmers see as important for themselves so the ability to look at an animal and be able to tell if that animal would be good for their farm and the health of that animal; that's kind of a visual skill that farmers are really proud of and is really part of what it means to be a farmer and part of the farming community."* – Social Scientist 1

However, others had a different interpretation of this risk. Data-driven decision making was viewed as a hugely beneficial asset for farmers. Smart technologies were viewed as taking the guess-work out of day-to-day decisions on the farm. For these participants, digital technologies did not replace the farmer; rather than technology dictating to the farmer, the farmer would still remain at the heart of farm operations. Data and smart technologies were simply used to accelerate or mimic the good heuristics of farmer-led decision-making. That a farmer's gut instinct could now be supported by data and evidence was viewed as a positive development. Rather than viewing technology as eliminating the good practices of farmers, these participants felt that the expert skills of farmers would probably change – farmers would be more tech-savvy and comfortable with data in the future. Rather than seeing this as a negative, these participants viewed it as a positive development whereby new high-skilled roles would be created within agriculture. For these participants, the future of farming was viewed as a blend of traditional and new skills.

*"It's not doing the farming for the farmer, but telling the farmer about the current status of the farm. And allowing them to make the decision, I think that's where it is. It's information."* – Computer Scientist 1

"*The role of farming may be as the custodian of the country side but it's also going to be the person that's at the forefront of collecting this data or being the focal point for all of these sensors. And it will require change but it can't be at the loss of traditional farming which is people outside putting their hands in the soil, you know it is still essential. You're still going to have to do that, you know you're still going to have to get into a cab and drive. Even with automated tractors, there will still be a requirement to get into cabs and program and assess and do all of this stuff as well. So it's a blend of traditional and the future is where we're probably going to end up with the actual you know."* – Farming Representative 1

### 3.4. Data sharing and the need for privacy and transparency

The most discussed issue amongst participants related to the risks which can arise when data is collected from Smart Farming technologies. There was significant discussion of various emergent risks and in particular the need to ensure the privacy of the farmer and to encourage more transparent actions in data sharing practices. All participants agreed that the farmers' rights needed protection but at the same time, some also cautioned that any solutions identified to address the aforementioned concerns needed to ensure that innovation and industry development was still supported. Participants indicated that one of the main strengths of Smart Farming is the analysis and/or aggregation of data for informed decision-making; in order for this to happen, data must be collected and shared. Some participants cautioned that strict rules, particularly in the form of legislation, regarding ownership and sharing of data could prevent progress of the entire industry.

*"A risk is stopping progress if you ban the use of data; you need variability in data which you get in huge amounts of data – this is needed to advance research and innovation, companies do need access to data. But if farmers buy equipment from a company then they should be allowed to own that – that's a basic right; a company should not be taking advantage of this"* – Agricultural / Food Scientist 2

Amongst all participants there was a sense that the issue of data ownership and data sharing is particularly grey, contested and uncertain. Many participants were of the view that it would take only one data-related scandal to hit the headlines and severely impede the development of Smart Farming. Participants called for urgent coordinated action, specific to the context of agriculture. There was universal recognition of data as an issue demanding urgent attention although participants' identification of risks did differ. Underlying participants' interpretations of the risks of data sharing were two basic ethical principles: (1) an individual's right to privacy and (2) the need for transparency.

Many participants held the belief that farmer's had a basic right to privacy where their data was concerned and it was stemming from this belief that a number of risks were perceived. Some participants believed farmer's had the right to know what data was being accessed, who was going to access their data and how it was going to be used. They felt that once answered, these questions would greatly determine a farmer's willingness to grant informed consent to their data being used. These participants felt that farmers would have little concern about their data being used under the right conditions: pre-existing trusted relationships, well-known long-established processes of data-sharing and/or the presence of certain value propositions. For example, some of the scientists in the sample indicated that they found it quite easy to collect data from farmers for use in publicly-funded research. Participants also pointed to circumstances in which farmers may be less willing to share their data. Farmers, particularly those operating family farms are viewed as having an intense and personal connection to their farm. The farm business and farm household are often interconnected; as is the farmer's personal identity. Thus, it was felt amongst participants that perceived intrusions of sensitive or personal farm data would be viewed under a very emotive lens by the farmer and could act as a barrier to smart technology adoption amongst farmers. Particular areas of sensitivity related to animal health which was associated with a farmer's fear of being stigmatised, as well as regulatory compliance which was associated with a farmer's fear of being penalised. In this sense, the concept of data sharing triggered concerns over the ability to maintain and assure the privacy of individual farm-level data.

*"I could see them being worried, you know I suppose by the very nature of farmers. And the fact that they're hugely private in and around their own personal farms. I could see them being concerned if that data was to be passed around freely. And that their farm would be connected in some way to that data. And their farm and their acreage, their farm family, their production levels would be connected to that and connected to their name. I think that could be a huge issue."* – Social Scientist 3

Sharing and aggregating data for the benefit of the farmer, the farming industry and the collective good was viewed as an exciting opportunity; however, a large number of participants indicated that this could not be at the expense of failing to protect the individual farmer's right to privacy.

There was a sense amongst many of the participants that a lack of transparency existed in how data is currently collected, stored and shared. A number of participants feared that farmers have a lack of awareness as to the extent to which their data is shared and used by third parties. Inconsistent business models and a lack of clarity around contracts and terms and conditions were viewed to ultimately lead to farmer confusion, and possibly inertia and/or a feeling of helplessness. There was a sense amongst the participants that this is a particularly uncertain area and that the concept of privacy is multi-layered, with a lack of transparency and an audience of farmers who may not know the means to which their data is being used or distributed:

*""If you have a machine that is collecting data using sensors, who actually owns that data, when you download the data on to your own computer are you the person with the sole copy of that data…I think the privacy is multi-layered - it's not so easy when, let's say a USB is taken out of a machine and brought somewhere else well it's nearly impossible to know where these things go."* – Computer Scientist 3

A number of participants held particularly strong beliefs that by sharing their personal data, farmers had certain rights to at least know about, and possibly even share in, any financial benefits which may accrue from the use of that data. Data was viewed as a valuable commodity but participants questioned the extent to which farmers themselves were aware of this. There was some concern that where commercial outlets may financially benefit from farmers' data, farmers may not be able to see the value of their own data and even if they did, they may not have sufficient bargaining power. Participants felt that current power dynamics and inequities in existing relationships between farmers and industry would leave farmers at risk of being exploited by data-sharing business models:

*"It's not just an issue of farmers trust, it's also an issue of people's rights and that those aren't breached. So ensuring that they have control over the data and that they consent to how it is used in different forms and that it's not linked up to things that they don't want it to be. And because a lot it is the hands of private companies as well…. And because farmers in general don't tend to be all that powerful within the whole supply chain, you know they can't dictate prices and they are often seen to be at the mercy of commercial organisations and the government. So*

*safeguarding their rights is important from the outset."* - Social Scientist 1

A few participants also questioned the potential for more malicious practices to emerge through a lack of transparency in how data is used; for example, whether agribusiness could potentially use knowledge of local farm operations and attributes to engage in discriminatory and customised pricing or product recommendations:

*"I think there is certainly concern where people, maybe processors, supermarkets, companies like that can acquire data and use data in a way that could be negative to the producer. In other words, the person who is going to purchase the product from the farm could know almost everything about that product, including its production cost and that then gives them a huge leverage that if they know to the cent what it costs to produce well that's the price that's going to be offered and nothing else. So I think there is concern there."* – Agricultural / Food Scientist 1

However, from the perspective of the AgTech participants interviewed in the current study, the importance of responsible practices related to data sharing was high on their priority so as to ensure the trust of their clients and the ultimate success of their company:

*"We see privacy as something that's very important. I think there's going to be actually an explosion in that area, at a certain point in time. Because you've a lot of people talking about the value of the data. But if you were using that data and giving it to somebody else, other than the farmer, I think they'd drop you in a shot. Our view is that we cannot do anything that would be a breach of trust – that would be catastrophic for us."* – AgTech Industry 3

*"Our farmers, they're our supply chain, they're our raw material and if we mess them around there goes our raw material, we've got nothing to sell. So we have to serve them and we have to do things properly."* – AgTech Industry 1

## 4. Discussion

The current study reveals how key governance actors view the development of Smart Farming in Ireland and the risks and benefits they anticipate increased digitisation in agriculture will bring. Although the participants in the current study were largely in agreement about the benefits presented by Smart Farming for Irish agriculture and society, they held different interpretations and opinions when discussing identified risks. While Smart Farming has the potential to be an extremely positive development for Irish agriculture, there are issues which need to be critically considered to ensure that the benefits do outweigh the risks – particularly, as identified in the current study, for the farming population. Exploring anticipated impacts of Smart Farming through a theoretical lens of risk perception and ambiguity in the current study reinforces the basic tenet underlying RRI: informed by their own values and life experiences, different actors are likely to hold different opinions about the social, behavioural and economic consequences of technology within society. It is for this reason that frameworks such as RRI are needed within Smart Farming to facilitate a process which acknowledges and accounts for these different values and interpretations.

In considering the specific risks identified in the current study, the main concerns related to consumer rejection of technologies, inequitable distribution of risks and benefits within the farming community, adverse socio-economic impacts of increased farmer-technology interactions, and ethical threats presented by the collection and sharing of farmers' data. Previous research has also identified these as issues of concern for the development of Smart Farming in other countries (Carolan, 2016; Fleming et al., 2018a; Jakku et al., 2019). Awareness of the potential for societal disquiet and consumer rejection of specific technologies was an issue of particular concern in the current study. In contrast to other identified risk issues such as data sharing and power imbalances, this is perhaps an issue which has received comparatively less attention within the Smart Farming literature although societal attitudes towards technology have been widely studied in other fields (Devine-Wright, 2011; Scott et al., 2018). This could stem in part from the different definitions which have been used to define and conceptualise Smart Farming in the literature (Wolfert et al., 2017b). In the current study, at the outset of the interviews, participants were encouraged to debate and discuss their understanding of the term 'Smart Farming', allowing them the freedom to introduce issues they felt were pertinent to the discussion. While some viewed Smart Farming as pertaining only to technologies used within the farm gate, others considered technology and innovation right across the agri-food sector including for example, the application of genetics. The opacity which often accompanies the vernacular of digitisation in agriculture needs to be addressed, not least because the confines afforded to such concepts will shape future digitisation policy and strategy.

With a strong indigenous Irish agricultural industry and an emerging tech sector, participants viewed Ireland as being in an opportunistic position to develop a strong national AgTech identity. However, this enthusiasm was tempered by participants questioning the impact of Smart Farming at farm level, particularly on smaller family farms and older farmers. In line with previous concerns that Smart Farming will serve to amplify the digital divide (Fleming et al., 2018a,b), participants in the current study feared that certain farmers could end up being marginalised down the line. The impact of digitisation across different farm demographics requires particular consideration within Irish agriculture given characteristics of the agri-food landscape. Numbered at 137,100, family farms in Ireland account for 99.7% of all farms with more than half of farm holders aged 55 or over while just 5% of farm holders are aged under 35 (Central Statistics Office, 2016). In Ireland, there is already a stark contrast between those farmers who are already using smart technologies, and those farmers who do not yet own or use a computer for their farm business (Hennessy et al., 2016). In many farms, there is still low uptake of more mature technologies such as computers and smartphones. For example, in Ireland in 2015, across dairy, cattle, sheep and tillage enterprises, smartphone usage for farming purposes had adoption rates of between 9% and 37% (Dillion, 2018). Participants were also concerned about the potential impact which technologies may have on farmers' skills and heuristics which brings into question the values which are promoted by Smart Farming. Some commentators have noted that the imagery, messaging and framing used by agribusiness in their communications around Smart Farming promote a narrative of Smart Farming related to a productivist model of farming, which may favour a particular type of farmer (Bronson and Knezevic, 2016; Carolan, 2016; Ge and Bogaardt, 2015). As evidenced in the current study, the impact of Smart Farming on different types of farmers and farming sectors is a risk issue particularly shrouded in ambiguity and will likely give rise to considerable debate. To prevent the marginalisation of segments of the farming community, consideration will need to be given to how the diversity of the farming community (Ge and Bogaardt, 2015; Hoes and Ge, 2017) and how the concept of the 'good farmer' (Burton, 2004) are reflected in the terminology and imagery used to communicate digital advances in agriculture.

The current study explored the level and nature of ambiguity present for each of the identified risks. When discussing future impacts of increased farmer-technology interaction, some participants were concerned about the potential social risks that an over-reliance on technology might bring but others viewed technology as an opportunity to upskill and enhance the farmer. There was evidence of clear disagreement about the existence of risks when it came to considering the expected impact of digital technologies on farmers, particularly where it came to reflecting on the impact of technology on small farms. When discussing the issue of data sharing, all participants viewed some level of risk but the nature of the risks identified varied across participants. Finally, participants – although very enthusiastic themselves for the positive impact Smart Farming could have on society – were more than aware of the potential for opposition and rejection of certain technologies by consumers and society. Defining risks based on their level of ambiguity is important as it will inform the strategies required to manage these risks. Under Renn's (2008) process model of risk governance, high ambiguity calls for discourse-based management which bears strong parallels to the principles set out under RRI: facilitating all relevant actors to debate and discuss the risks, identifying common values and fostering a mutual and collective understanding to develop acceptable or tolerable strategies (Stilgoe et al., 2014; Von Schomberg, 2013). Ambiguity exists because individuals hold divergent value judgements on a given issue (Renn and Klinke, 2014). Identifying ambiguity in the presence of risks reminds us that evidence or information alone will not be sufficient to develop solutions. Risks will always be interpreted through different lenses irrespective of the information available and it is for this reason processes such as RRI, which advocates for participatory engagement, are needed.

Recent evidence suggests that we have more work to do to integrate diverse stakeholder perspectives in the governance of smart technologies in agriculture (Eastwood et al., 2017). In dealing with the ambiguity identified in the current study, all relevant actors including farmers and civil society ought to be actively involved in solutions-oriented decision-making (Wolfert et al., 2017a). This not only empowers those actors most directly impacted by such decision-making, but leads to increased legitimacy in and ownership of the decisions made, and ultimately facilitates better decision making (Fiorino, 1990). RRI is intended as a framework to guide the development and introduction of new technologies in a manner which identifies, accommodates, responds to and addresses societal concerns (Asveld et al., 2015). The RRI approach is not one to be implemented separately or in parallel to research and innovation activities; instead, the principles which embody RRI are embedded *within* research and innovation activities. Recent papers have made concrete suggestions as to how RRI can be built into the Smart Farming research and innovation process (see Bronson, 2018; Eastwood et al., 2017) including for example, deploying deliberative forums, supporting public-private collaborations, embedding social scientists within inter-disciplinary projects and integrating user-centred design approaches. The engagement fostered by such RRI exercises not only generates an atmosphere of trust, it also encourages reflexivity. For example, interacting with farmers and consumers can trigger other actors (e.g. scientists, industry) to understand potential areas of divergence in opinion and reduce the risk of making incorrect assumptions about their values.

## 5. Conclusion

Viewed by many as invaluable for the future success and sustainability of the agricultural sector, Smart Farming has the potential to overhaul and transform the way farms are managed and operated (Kamilaris et al., 2017; Wolfert et al., 2017a). The advent of Smart Farming in agriculture offers exciting developments but also potential challenges and risks, as is the case where any new technologies are introduced into society (Sonka, 2014). However, there is a dearth of empirical data and knowledge on current socio-economic impacts of digitisation. Research is needed to address this and to chart and plan for future impacts. By engaging key decision makers, the current paper offers insight into the anticipated negative and positive impacts which may arise with the introduction of Smart Farming technologies. Insights from the current study can help to frame specific values-based questions for further consideration in RRI exercises by key governance actors driving the development of Smart Farming (Bronson, 2018; Fleming et al., 2018a). Such questions – formulated based on the qualitative findings of this study – could include: the impact of digitisation on small family farms *(what role is there for small farmers in Smart Farming?)*; the issue of data sharing and data ownership (*how can the ethical rights of farmers be protected whilst also supporting innovation which depends on data collection and sharing?*); the role of consumers and general society in this debate (*how and to what extent should consumers and civil actors be engaged in decision-making around Smart Farming?*); and proving the value of Smart Farming for farmers (*how can the value of digital technologies to all farmers be best validated and demonstrated?)*. Considering these and other questions at the early and ongoing stages of policy development, product design and within scientific projects can assist in accommodating and addressing societal concerns, and insofar as is possible help to develop coping strategies which can mitigate unanticipated negative consequences. Anticipatory governance is important and the decisions that are made now will shape the agri-food sector for the years and decades to come. It is important to ensure all key actors are central to conversations on the development of this field (Eastwood et al., 2017). The current study is a first step in outlining some of the key issues facing Smart Farming in Ireland which need to be further considered and addressed through RRI exercises embedded in future research and innovation activities.

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