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The Why?, What?, How and Who? of Innovation - Professor Julie Ingram's Inaugural Lecture

Thank you. How lovely to see you all. And thank you for coming. That was quite a build up. I hope the expectations aren't raised too high. So the title of my talk, as you've spotted, the words have moved around slightly since I submitted the first description of it. But what I hope to do today is to take you through a little bit of a journey through these different why, what, how and who have innovation, and that you go home with a different understanding and kind of test some of your assumptions about innovation in agriculture. I mean, innovation for us all is quite a buzzword. So as I said earlier, I want to unpack it slightly and make it more accessible for everybody. And in case you're curious about the choice of picture, you will have to wait and see about that. Unless you've got some thoughts now.

So a little bit of structure about what's going to happen, it seems quite customary to talk about your influences and career journey at these inaugural lectures. So I'll spend a little time doing that. Then go into the substance of the lecture about the why, the what, the how and the who, and the evolution of ideas and theories that have accompanied those questions. Drawn on a few examples from my research projects, talk about what next and then have a very short conclusion, and then release you all for a drink.

So my influences and career journey. I think the first word that comes to mind are stories. I was brought up with stories. My father was brought up in India and my grandparents. We have many conversations around the dinner table about exotic places in India. In fact, my father is the one here with a silly hat on. There's my father. So we had a lot of exotic stories in the family. And I began to realise in my rather suburban family upbringing in Reading that there was a different world out there to explore. My school years were spent inspired by a fantastic geography teacher, a kind of Miss Marples character who was called Miss Short, who had travelled the world and had a story to accompany every lesson in her, in her Geography GCSE course. And she was truly inspirational. And she encouraged me to go on

and do Geography, well actually Environmental Science at university, where this book was a constant companion called, 'Big Holmes'. It must have weighed about two kilos, that again, was packed full of stories of physical geomorphology drumlins, deltas, volcanoes, wave cut platforms, stories about rocks exploding in the desert. Arthur Holmes was a well travelled chap, and really gave a lot of excitement to geography and geomorphology. I mean, who doesn't love a wave cut platform? So I couldn't continue without mentioning another major influence in my life, which some of you will know, I'm a Monty Python fan being brought up in the 70s. It was there in the background all the time. And I wanted to share with you my very first rejection letter from the producer of Monty Python. Goodness knows what I sent in. But anyway, this is my response, handwritten. And it says, Dear Miss Tear, thank you for your splendidly loony letter. Unfortunately, We're not making any more Pythons in the near future. Therefore, I'm returning to you, your ideas and the hope that you may be able to make use of them elsewhere. I think we probably all know what that means. Anyway, I've kept this letter. I've had many other rejections since, but I haven't kept those.

So thinking about a career journey. There's a hint here that maybe I was interested in soil auguration instruments early on. It wasn't straightforward. It wasn't a conventional A to B, it was very much a lot of distractions and trying different things along the way. But I eventually ended up doing a Natural Environmental Science degree at Sheffield, one of the first in the country, and then went on to do a Soil Survey and Pedology masters at Reading University thinking this might be my ticket to go travelling around the world and work overseas. And indeed, that was the case. So having graduated from Reading, my first job was in Swaziland, where I worked for the Commonwealth Development Corporation on a sugarcane estate. And here's a picture of me, I had my own truck, my own team to dig holes for me. So there was a lot of looking down holes. The idea was to grow as much sugar cane as possible. It was a big commodity crop for Swaziland. And to map the

soils and work out where the deficiencies were, where the irrigation requirements were. So there was a year or so there.

And then moving on to Nepal, where I worked for the ODA as well as then DFID, as was then, on a Forestry Research Project, and more looking down holes. I was part of the soil survey team. I think you could probably spot me there in the front row, where we used to go on campaigns. The intention was to try and establish more trees in the middle hills of Nepal. And as you can clearly see, they are desperately needed. But it was my very first introduction really to people in development, because lots of my colleagues, they were working in community forestry, which was quite an established institution in Nepal at the time.

And then moved on there to Zimbabwe, where I had my very first experience of participatory approaches. Working with the Commonwealth and Science Foundation, on a rapid Rural Appraisal for agroforestry. I think we spent about six weeks talking to various villagers about agroforestry. From memory, I don't think they were particularly interested in it, they were interested in other aspects, but they really threw a good party, as you can see. So from there, moving on to Kenya, where we had two or three years and bouncing a baby on my knee and doing various soil fertility reviews of looking in past empirical studies and experiments from long term experiments that were conducted in the Kenya Agricultural Research Institute in Malawi, and various places and had these publications. At this point, it probably occurred to me that there was a huge amount of research being done and kept away on dusty shelves in libraries, not actually reaching the people it was intended to reach. And these were quite topical practices being investigated things we're looking at now actually, like soil organic matter, management, intercropping. All very relevant aspects to farm management that we look at today. So these were my, my formative years thinking, hang on a moment, there's a lot of research happening, and how's it getting down to the farmers.

So back in England now, having had time to ponder those questions, I discovered CCRI. Managed to get an ESRC studentship. And that led me to the PhD that Jackie just mentioned. It also immersed me in academia, Rural Sociology, which was terrifying at the time, and introduced me to the concept of agriculture, knowledge and innovation systems, which really has been a framework of my work ever since. So these were the formative years.

Now on to the substance of the lecture. I think the reason why I swapped those whys and whats and who's and hows around is that I really didn't know where to start. There was no entry point because everything is all interconnected. I'll start however, with a why, and then see how we go because the who's and hows I think probably get bunched up together.

So the why, quite simply for innovation in agriculture is to provide a solution. And in simpler times, it was solution to the problem as we need more food. Whether that was in Western societies post war. The requirement for more food to be grown or whether it was in developing countries where the risk of starvation was very, very persistent at the time. So the drivers were food insecurity. We had these uniform policies to promote more food production and simple supply chains at the time. So consequently, research was, innovations were very research led and had a very technological focus. And that was the same whether it was in developing countries, and was actually the logic for the Green Revolution as well. And this was accompanied by great developments in fertiliser, pesticide inputs, plant breeding, irrigation, machinery, all the institutional and technological structures that accompany this industrialised food production.

However, now if we ask why, innovation needs to address much more complicated problems. We call these wicked problems, almost intransigent problems, climate change, food insecurity, but not just growing more food, making it accessible to more people, biodiversity, land and water degradation, a lot of these as a consequence of the industrialised agriculture that we've been promoting. We also have multiple policy objectives, sustainable agriculture, and the three pillars of sustainability, mitigation, adaptation to climate change, animal welfare, ecosystem services, providing clean water, provisioning for food, and so on. And then this landscape of market forces, the global markets, the economies of scale, that really steer the farmer towards efficiencies and economies and competitiveness. Coupled with the rising consumer demand, the demand for quality and affordability and food as well.

So these complex problems require different solutions, and different innovations. And in the words of the European Commission, knowledge and innovation are essential for this new, smart, resilient and sustainable agricultural sector. So not just growing food anymore, we have to meet all those demands. And that's not just the case in the EU, it's the case worldwide, which the sustainable development goals reflect where again, innovation is one of the core, the goals of those, the goals of those goals.

However, let's just pause here and think for a moment about the question of why innovation. Innovation is not inherently good or value free. It's always driven by different worldviews and visions and different development trajectories, and pathways. There'll be winners and losers. And there'll always be trade offs. And as we've seen, there can be negative consequences as well. So in the words of Mencken, an essayist from America, that 'every complex problem, there's an answer that's clear, simple and wrong'. And this is reflected in a comment from Norman Borlaug, who's known as to be the Father of the Green

Revolution, who acknowledged this by saying 'my work was a change in the right direction, but it's not transformed the world into a utopia'. So technological innovations are great, they can meet certain goals, but as a consequence, they create others. So there's just to a little cautionary tale that innovations are not value free.

So going on to the what, what is innovation, there are various definitions depending on what framing you're using, and what theoretical tradition you come from. But essentially, they're creative ideas that are addressing a problem. This first definition, 'any idea of practice or object that's perceived as new by an individual or a unit of adoption'. So the perception is that being new is worth noting, because in some contexts, it might not be new, but in other contexts it is. It can include development and application of new knowledge, materials, tools and practices and here it's equated to a technology. So note the word knowledge there which is critical to innovation. It brings about a significant positive change, for example, like an increase in crop yield or better management. And here adoption is seen to be the prize. So innovation and adoption are seldom not heard together. And the definition that the European Innovation Partnership has adopted is 'ideas put into practice with success'. So the successful uptake or implementation has seemed to be key to an innovation. And that's captured in this comment here by Edison. 'The value of an idea lies in the using of it'.

So thinking about innovation, I expect we will have assumptions or thoughts about what we think innovation is, and we often think that technology in farming so new kit, for example, the quadbike has been an innovation for upland farmers. The picture at the bottom believe it or not, is an auto-pollinator. So where there are no bees, don't worry, we've always got a machine that can do the job for you. Or new tools, decision support tools. If a farmer wants to know what the weather patterns going to be, or some advice about soil moisture, for example, there are apps that can tell you now. Or tractor mounted yield monitor or GPS system for auto steering. There are new products, soil ameliorant, soil improvers, bio inoculants, seaweed diets for cows to reduce emissions and new crops. Pharmaceutical crops like this forage crop you might have seen in the fields nearby miscanthus, bioenergy crops. But they can also be new practices and new systems, new practices such as cover crops, herbal lays, mob grazing. If you listen to The Archers, no doubt you've heard some of these mentioned. Systemic changes can be an innovation as well. We have a whole list here of environmentally orientated and ideological, if you'd like, systemic changes such as organic farming, conservation agriculture, and the list goes on. I expect regenerative agriculture is one that's particularly popular at the moment, and rewilding. Or you can have different sorts of systems change, Precision farming, vertical farming and smart farming, which is very production driven.

Being an academic, we like to categorise innovations in terms of incremental, is a gradual change and continuous improvement of existing practices,. Farmers have been using trial and error for a long time. Tractor manufacturers have been tweaking tractors for some time as well. Or we could have a radical change. A major change, which is something that's game changing or breaks the rules like organic farming or smart farming. Or retro innovation, where developing knowledge and expertise from the past is combined with modernised ideas from the future, such as a traditional farmers market that's assembled through WhatsApp for example, or artisan food production with new technologies, heritage wheat breeds maybe using new machinery. Or what about this as an idea? There is something wrong in this picture, I don't know if

anyone can spot it, but the gas mask is at the wrong end!

So coming to the how and the who. They're really quite inseparable. So I think we have to deal with them together here. So these are the sorts of questions we ask as academics. How to achieve more innovation if we assume that innovation is a good thing. So what motivates users to adopt or reject innovations? What are the barriers? Who innovates? And how are the ideas shared around? How can these innovations be supported? Are there policy instruments we could use? And how can they address specific challenges at scale? It's all very well having small networks or people twiddling around on the farm, but how can they enable a much bigger transition to a more sustainable agriculture.

So with the transformation of agriculture over the years, there's been an evolution of ideas and perspectives as well. Moving from the bottom here, the technology transfer, the bottom bubble, all the way up to more of a systems view. Technology Transfer was an early linear approach that focus very much on the individual transferring technology or recommendations of packages of practices, concentrating so very much on the innovation itself, and providing information. We can think of it as an information deficit model if you like. If we give farmers the the knowledge and the technology that will be fine. Then that was critiqued and found not to be particularly successful. Farming Systems Research as a new paradigm, where we introduce participatory approaches and realise that farmers themselves have knowledge that we could use and that the farmers generated and talk to each other and shared knowledge.

Moving on then to talk about agricultural knowledge and information, and then change to innovation systems and agricultural innovation systems. These are organisational frameworks if you like to help us understand how those different knowledge flows around. And knowledge and innovation are key here. So as we move up this embedded layer of circles, we moved from a focus on transferring information around to trying to

build capacity and knowledge, to really thinking about how we can instil learning. And then at the very top, we get to what's called the socio-technical systems where we really zoom out from the individual, and even the farm, and think about the much wider system and that enables those innovations to emerge, and to be shared, and to be embedded and institutionalised. And as you say, this was an answer to a growing complexity in the agricultural landscape as those wicked problems and those different imperatives on farmers in the farming community grew stronger. And this has been accompanied by different ideas and theoretical thoughts about how innovation happens and spreads. This seminal book by Rogers, first published in 1962, but actually formed from ideas in the 40s, in Iowa in America, where there are large studies of the spread of hybrid corn amongst Iowa farmers. And Rogers consolidated these various ideas, and developed the idea of diffusion of innovations, which was premised on awareness and giving knowledge to farmers, and then seeing how those diffusion of ideas spread. It was a very successful theory. And in fact, the book is in its fifth edition now, and some of the ideas are still quite pertinent to today, particularly his ideas about social systems and sharing information amongst farmers. But it came from a particular tradition of focusing on the individual and the technology itself can be thought of as quite top down, or, as I say, thinking about information as the only deficit.

Another tradition, Farmer First, which some of you might have heard of Robert Chambers, from the 1980s, started to critique particularly in the developing world, this notion of just giving information and technologies to farmers and expecting them to adopt it. And farming systems grew out of that. So this notion of having more of a bottom-up approach to innovation, encouraging social learning, encouraging participatory approaches between researchers, and farmers and extension workers more as a partnership.

And then we've moved on to think about innovation systems, drawing from industrial innovation systems, and theories from their evolutionary economics as well. So these different bodies of work and traditions have fed into thinking an evolution of perspectives over the years. Thinking about these earlier behavioural studies then with the focus on the individual in the technology, the question really was then why won't farmers adopt? What are the barriers? We've given them all the information, we've given them the technology, you know, what's, what's going on? And a lot of behavioural studies have looked into this question and tried to explain innovation and adoption in terms of various factors. But it became quite apparent that farmers weren't behaving in a rational way. They weren't acting as rational decision makers, or optimizers. But they were what Simon called 'Satisficers'. And that no single factor could explain individual adoption. There are a lot of pertinent factors but nothing in particular. And as Vanclay says, 'there's

no such thing as a barrier to adoption, there's just only legitimate reasons for non adoption'.

So, as I said, a lot of behavioural studies have looked into various factors that explain adoption, the uptake and the rate and the diffusion and so on thinking first of all about democratic factors, education, farm size, age of farmer, thinking about extrinsic motivations. Economic motivations, of course, are very important. But also thinking about the intrinsic motivations, the attitudes, the values and the identity. But then it became apparent that community and society were also equally important. Farmers are embedded in their own cultural communities, they have cultural norms, they have habits they developed, and they respond to social pressures as well. At the same time, they're restrained in their adoption of innovations by whether they own the farm or not, or whether they have to pay rent, what kind of infrastructure they've got, whether they're rich in capital, whether they have debt, what their labour capital is, and where they are on the farm lifecycle, as well, whether they're about to pass on their farm to a son, or whether they're just starting afresh in farming. And also where they are in terms of their knowledge system, if you like, what their peer to peer exchanges, where they get their advice from, and what their social system is.

So it became apparent that it was quite hard to predict how farmers behave when it comes to innovations and whether they will adopt them or not. And this is captured quite nicely in this picture of an Amish community in America. I mean, who would have predicted this, that they would have adopted the mechanical baler but not the tractor? So there's a lot of cultural, religious traditions, family traditions and values their, and economic imperatives, explaining that.

So, adoption has been critiqued, particularly the linear technology version of adoption has been critiqued over the years. The 'Rural Sociology' journal, 'Agricultural Extension and Education', and more recently, FAO's work in innovation have really emphasised that the farmer as the user of that technology has to be involved in the research system, and it has to be part of a collaborative network to succeed. Because we know that farmers generate their own knowledge and share it between them. External innovations are never particularly relevant for small farmers, small scale farmers. Adoption rates have often been low. Farmers have been disempowered by being part of a system they're locked into with high inputs and also a realisation that innovation itself is not a simple on off switch. It's not a technological device or package. It's much more than that. It's about learning and adaptation, and it's a complex process. We've also come to realise that farmers are not particularly homogenous, we can't just talk about a farmer. They're very heterogenous.

So we've moved on, if you can think back to those circles to the middle circle now and think about innovation is a more networked activity. This is addressing the more complex socio-scientific

problems and requires mobilising this range of stakeholders with multiple perspectives. So we're not just thinking about the farmer now we're thinking about the farmer's interaction with his agronomist, or with a policymaker with a supply chain contractor, with a retailer for example. An innovation now is seen to produce more as co-produced as people bring their different combinations and knowledge together from different sources. And the questions that emerge now is how to get these networks to work at scale, how to upscale them, that's to embed them in the system and how to out scale them, how to replicate them and diffuse them.

So we moved from this very linear agricultural knowledge system view where we've seen knowledge flowing from research through extension to farmer, to something a lot more networked, where all these actors are linked together and can form networks amongst them, for example, accountants and input suppliers, farmers and researchers might be a network together, acting together. And this is what we call the agricultural knowledge and innovation system. It's quite a useful framework to understand what's going on.

And moving on to that very last circle and the diagram from earlier. I'm drawing on the socio-technical systems. This sees innovation as much more of a technological, social, economic and institutional combination. It's not just about adopting technologies. It's about new social and organisational arrangements. New rules, perceptions, procedures, institutions can be thought of as the rules of the game if you like, the way things are done, and can explain how we get stuck in certain regimes or certain ways of acting.

So look away now if you have an aversion to complex models! But I couldn't not mention this transition model, which came out of the system's thinking. It's called the multi level perspective, and actually, it's not as complicated as it seems. If you think about a transition as moving from one system to another, for example, from a conventional agricultural system to a more sustainable one, you can think about it as arising out of the interplay of three levels. So starting at the bottom, we have the purple arrows are the networks. Networks, bringing together radical ideas amongst different groups of people, and working in protected spaces called niches, and experimenting and learning together. In the middle layer, we have the regime the status quo, if you like. It's stable. It's created by those institutional, technological economic dimensions I mentioned earlier, and people are locked into it. So through this co-evolution of those dimensions, there's a lock in, and there's no entry to those networks from down below., except when you can get some sort of tension in that regime, and cracks, which those networks can find a route into. And often these are created by windows of opportunity, from the landscape level, that's the top level. So for example, these are broad scale changes. If we

think about the war, or an energy crisis, very topical at the moment. They might create these windows of opportunity that create a tension in the regime, in which these networks can find a route in and start to change and reconfigure that regime. It's a complicated idea, and it's very functional and analytical and has been critiqued a lot. But it's, it's quite a nice framework to understand how these networks might make a change in a much bigger scale than just rumbling along the bottom here.

An easier way of looking at that is to take these three areas, hardware, software, and orgware and think about innovation is a combination of those. So software, we think about that in terms of knowledge, new modes of thinking, and skills and competencies. Hardware are the technical devices. And orgware, the social institutions and forms of organisation. And that's what's needed, really, for innovations to take off.

So just pausing, taking stock about the whys, the whats, the hows and the whos. Just things to remember. It shouldn't imply that the technology transfer models all bad or that networks and people centred innovations are all good. That elements of each are important for different circumstances. But what we really need to do is to challenge our assumptions and shift the frames of reference, which is why we have to think in different ways. So drawing on somebody quite famous and famous quote, I'm sure, we can't solve the problems by using the same kind of thinking we use when we created them. And of course, there are some innovations that are just quite frankly inexplicable.

Okay, so I'm going to give you a few examples now from my research. Well, I'll say my research, but actually all my research has been done in teams with my colleagues from CCRI. So from our research. And the sorts of questions we ask in our projects. The same questions I mentioned earlier. What motivates users to adopt and reject innovation? What are the barriers? How are these ideas spread around? What kind of peer to peer learning is there? How the farmers themselves innovate and experiment? How can innovation to address specific challenges at scale? And how can they be supported with policy for example? And how can they lead to wide scale transitions? How can we bring about a transition to more sustainable agriculture? The sorts of approaches we use. Participatory approaches often involve stakeholder engagement. We've talked about co-innovation, where we work together with farmers or agronomists, retail representatives. Co-design, where there's a genuine co-design of technologies from the very beginning. Citizen science. And then the sorts of methods we use within those approaches. Interviews, workshops, focus groups or serious games, for example.

Here's a selection of some European projects I've been involved with where we've answered some of those questions, or tried to answer some of those questions, and looked at different aspects of

knowledge and learning. These have been interdisciplinary projects, they bringing scientists and stakeholders together. And often our role at CCRI is to enable that to happen. I've worked in a number of soil related projects where we've looked at soil improving practices .at looking at soil carbon management and decision support tools, and more recently, as Jackie said, looking at plastic pollution in soil as well. In the Valerie project, we looked at translation of research activities, carried out co-innovation exercises with case studies across Europe. In Agri-Demo, we were looking at peer to peer learning in research activities across Europe as well.

In UK projects we've worked with all these organisations again, looking at farmers, behavioural aspects and motivations. For example, what are their motivations for joining agri-environment schemes? We've looked at several iterations of agri environment schemes over the years to answer these questions. Currently working with different universities across the UK to look at how perennial biomass crops can be upscaled to meet the targets that the government has set. So there we're looking at not only the farmers personal motivations for growing those crops, but also at the system and how it enables them to be grown at scale across the country. And we've also worked with innovative farmers and the Soil Association evaluating their Farmer Field Labs where farmers are working together to solve problems themselves.

I've also had the opportunity to work on some international projects. Recently, an OECD fellowship took me to Indonesia and Australia, where I worked with climate smart agriculture, and looking particularly at farmers experimentation. So farmer centric experimentation and what that can reveal in terms of battling climate change and adaptation. And had the opportunity to do some British Council sponsored research links workshops in Kazakhstan, Egypt, and South Africa.

So from all those examples, it's quite hard to find one or two that can I can share with you now. But the first one I thought I'd talk about which actually goes back to some of my PhD research was the transition towards non inversion tillage. To plough or not to plough. So ploughing has a huge cultural significance in this country. It's very functional. It's been very effective in creating a seed bed, burying weeds. Farmers take great skill and pride in a nicely ploughed field. It's very skilled occupation. Ploughing matches happen every year around the country, where people are judged by their tidy butts and other characteristics and criteria. However, it's hugely fuel and energy consuming, and labour consuming. And also by turning the soil over, oxidises the soil organic carbon, so there's a loss of carbon there.

So since the 90s, also, in this country, at least, a community of practice of farmers have been experimenting with minimum or reduced tillage. Zero tillage, conservation agriculture, regenerative

agriculture. There are different combinations of those depending on how much you disturb the soil. But the essence of it is you don't turn the soil over, you don't expose the soil to oxidation. You save a huge amount of fuel and labour. And that works particularly well with very large fields and farms, where there's maybe one or two farmers, or one or two labourers left to do the work.

So those were the early motivations for farmers to experiment. There were no machines at the time and often they tinkered around in their, in their garage and created their own. Or some of them were Nuffield scholars and had gone to New Zealand or South America or North America, had seen these machines and we're importing them back again. But as time went on, they realised there were huge soil health benefits as well. Soil organic matter really grew. Earthworm populations, soil biology really was really enhanced by these activities. So this information was shared around the community. There was a lot of experiential knowledge. There was very little support from any of the advisory community because the advisors themselves didn't have the opportunity to practice this themselves. And there was a lot of criticism from their neighbouring farmers who looked over the fields or over the fences and tutted about the untidy fields and the messiness, because there are a lot of weeds, and it really doesn't look particularly nice.

So there's this community that was building and sharing information over the years, and slowly merging, and this is something I wrote about, I think, in 2010, about the social and technical dimensions of this farmer learning. And then about three or four years ago, my PhD student, Kamilla, did some social network analysis where she was able to go and interview in this case, zero till farmers and talk about their influences, and who their social network, who they networked with, who they got information from who was most influential. The blue dots were the farmers that were interviewed. And the other coloured dots are their linkages like academia, agronomist, supply chain people. The depth of the line indicates how influential the link is. So some of these farmers have their own knowledge systems, if you like. Out on a limb here, this chap here has no mates at all. These people in the middle are really influential and well connected. And these are the ones that have been doing it for some time. They're the champions, if you like. The passionate, no tillers, the sort of person that the other farmers will turn to for information. And this is a really nice visual description of what's going on. It's a snapshot in time because these networks change over time, as people on the edges become more confident and move into the middle and themselves become influencers. But I think it's, it portrays quite nicely how some farmers are particularly influential and can lead this community. And Kamilla published this paper in Agricultural Systems, about the role of social networks.

And as the community has grown, the imperatives have grown as well to save fuel, and to meet carbon climate targets and to think about soil carbon. The extent of minimum tillage has grown across the country as well with estimates of more than 50% now of arable land in England having some form of minimum tillage or no tillage happening on it. And I think we can map this out quite nicely. This transition, we're looking at the software, the skills, the experiential knowledge, the long term experiments that farmers have been doing and learning together. And the orgware, the networks, the institutional organisations, informal networking, but also becoming more formalised through Groundswell which an event now that happens every year, we're about 3000, farmers attend and share information about regenerative farming and non-inversion practices, and also the hardware. Whereas before there were very few drills available. Now, there are more than 12 on offer in, his country. So these have all come together to allow this innovation to happen and to take off, and motivated as I said, by these targets for Net Zero, an interest in soil carbon, and also these motivations to save fuel and labour. So that's just one example.

Moving on to the next one, I'm drawing on SOLINSA, which was a project is quite old now. I think it was 2015 or so when it concluded. A European funded project that looked how deep changes could be made in the socio-technical systems to achieve sustainable agriculture. So thinking about transitions, and going back to these networks of actors and how they experiment together at the local level, and how they can become sources of radical innovation, these niche if you think back to that diagram. And the solutions that they propose they deviate from, and they're often resisted or stopped by the prevailing regime. The conventional food system if you like.

So in SOLINSA we looked at seventeen different sorts of networks. Just a few examples here. In Switzerland networks of institutions, advisors and farmers who are aiming to optimise their own fodder production and minimise as inputs from outside and exports as well. In the Netherlands, for example, we looked at care farming the different networks of farmers and policymakers from the health and the farming sector and how they could connect together. In Latvia, we looked at the growth of biomass on farm as well by bringing together these different actors in the network. And we looked at different characteristics of those networks as well.

So taking you back to this diagram again, our networks were rumbling along here at the bottom. So if you think about these networks here, they're rumbling along here, all the time, some of them won't work at all, they'll drop off, some of them will manage to make a change in the regime here. And the changes in the regime are enabled because we have these tensions. We have consumer preferences for certified food now. We have policy incentives that allowed biomass, for

example, and biogas to be developed in Latvia. And at the same time, we had these landscape changes, which created windows of opportunity, that create an allow these tensions, and therefore allow these networks to emerge.

And our particular role here was to look at the interactions between the niche and the regime, and question, this very analytical framework, and give some theoretical considerations to that. And think about more of the personalities and the people involved and the sorts of processes that were going on. Because whilst this is a beautiful, functional analytical framework, it doesn't exactly explain what's going on in the networks, the personalities there, the linkages, and the anchoring that's going on in the regime itself. So we were able to make some theoretical contributions in publications, but also, quite importantly, some policy contributions at the EU level. So these learning and innovation networks were actually quite foundational for the operational groups, which came out of the European Innovation Partnership a few years ago, which were supported by the second pillar of the CAP. So it's nice to know that we've have some influence.

And then, finally, to talk about what direction next. It's quite hard now to pick up Farmers Weekly or pick up a journal without reading about the fourth agricultural revolution, the digital revolution, if you like. So, agriculture has been thought of in terms of agricultural one, two, three and four, where one was early mechanisation. Two is post war mechanisation. And three, the Green Revolution. So digital revolution can involve GPS tractors, satellite imagery, sensors. It can lead to a fully automated farm. And that's what we call smart farming. And we've been looking together with colleagues at the implications of digital farming for the farming community because as a revolution, this is going to have quite significant consequences. Whether they're going to be positive or negative, has been a topic of conversation. So we can have quite light touch, if you like digital agriculture, electric tractors, or robotic weeders, or sensors on drones above the crop, or something that becomes fully automated where the farmer, there's a vision of the farmer sitting in his office, becoming almost a cyborg, and running the farm from there.

So there are clearly implications of this in terms of knowledge, not only for the farmer himself, losing his experiential and tacit knowledge of how to run the farm and his own decision making control as well. But also those that surround him. The adviser, for example, will have to rethink their professional identity and the farm family and all sorts of other relationships and power relationships that the farmer has. And we were able to conduct some work using a prioritisation exercise with stakeholders across the UK. asking what were their priority research questions for digital agriculture. We had about 195 questions submitted from 45 or so stakeholders across the UK and analysed these into seven themes. I haven't got time to get into

them now, but of the priority questions, there are a few examples here that reflect the kind of concerns that people have at the moment about where digital agriculture might be taking us. So for example, how can data sharing be underpinned by a governance system which takes care of ethical concerns? So ethics is a really key concern here, because of the data capture and the commercial interests of large companies. What's the value that farmers get out of using these data compared with more traditional datasets and intuitive forms of decision making. What is the value to the farmer? Why don't they stick to their usual day to day or heuristics of their youths. And then what are the likely effects of digital technologies on farming identities, and on the power and knowledge relationships between farmers and other food actors? That's just an example of the 27 priority questions that emerged. But it was it was a fascinating exercise. And there's certainly a lot for researchers to do there in the future.

This was a collective paper we had published recently in Land Use Policy. So prioritisation exercise, allowed us as stakeholders to publish this paper as a collective group of academics. And that raises questions about responsible innovation. Responsible research and innovation is very topical now because we need to ask what sort of future do we want not only with things like digital agriculture and smart farming, but biotechnology as well. GMO crops were a topic of conversation a few years ago. Do we want the same. Do we want the business as usual? Do we want to reinforce the industrialised models of agriculture where there might be disempowerment? Ownership and control of data were real concerns. The loss of knowledge and autonomy on the farm and the digital divide where you have some haves and some have not. Some farmers won't be able to engage in digital agriculture at all. And this is quite a telling quote. It's a commentary by Nature, about when Monsanto bought Climate Corporation a few years back, which is a weather predicting service. Monsanto is hoping that adding detailed climate data to the mix, no doubt via electronic delivery to farmers, GPS, and precision ag machinery and record keeping systems, will be one more reason to stick with the big M. So it's about this data capture, power and control of the farmer that's a real concern.

Or do we want a different sort of future where technologies can enable agriculture, ecological futures, they can provide actionable knowledge for farmer decision making, they can support networking communication, farmers can share their know how their experiences and data and farmers themselves can be co-curators or co-creators of this knowledge. And there's some great examples of something called 'farm hack', which emerged out of America, where farmers themselves have taken control of that data and are steering their own future. So to achieve this, not only do we need to incorporate the user perspectives into the development of these technologies, and make sure we have these collaborative networks, we also really need to think about responsible research and innovation, which is about anticipation, anticipating what the future might bring, being inclusive, being responsible and responsive.

So, the end. Conclusions. I think I can just conclude by saying and reminding you that innovation itself is a social process. It's a socio-technical process. It's just not about adopting technologies. It's not value free, we need to be responsible and think about the innovations of the future. And as a researcher, working in innovations, and participatory approaches, you get to meet some great people and get invited to some great parties. Of course, innovations are all around us all the time. If you think back to the multi level perspective. Along the bottom, those niches have been there all the time rumbling away and some of them are just forgotten or not even noticeable. And of course, some of them just don't fly. And that comes back to my early picture. This picture is called...does anybody know? It's The fall of Icarus in the Landscape. So if you look very closely, you will see a pair of legs here, where Icarus has dived into the sea. And the point being made is that life goes on as normal, lots of things are happening around you, and you don't notice these different activities going on. So we don't notice all the innovations that are there, that are cropping up and then failing in the background. So it just leaves me to say, thank you very much to my support team CCRI. This is a very old photograph, and I apologise to those who aren't in it, and in particular, the family.

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