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Robot-ready: How apple producers are assembling in anticipation of new AI robotics

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ABSTRACT

With the growth of new collaborative design (co-design) strategies for technology development, and increasing media attention on future automation of the farm, food producers are aware of new robotics on the horizon. This paper will discuss how apple growers are anticipating new robotic technologies intended to use artificial intelligence (AI) to automate aspects of the farm, paying particular attention to the ways that anticipation relates to preparatory assembling and reassembling of landscapes, work, and institutions. Our analysis considers the varying ways growers are practically assembling their orchards in anticipation of new technologies, and how their actions map onto ecological systems, labour relations, and farm capitalization. Our findings reveal some of the challenges to democratic forms of engagement with a robotic future, as well as some of the ways that growers enhance their capacity to engage meaningfully with new technologies.

1. Introduction

"Quivering and hesitant, like a spoon-wielding toddler trying to eat soup without spilling it, the world's first raspberry-picking robot is attempting to harvest one of the fruits." (Kolowe et al., 2019).

"Down a dusty road west of Napier, a screeching robotic noise reverberates through apple orchards … The robot could have major ramifications for New Zealand's fruit-picking industry, which nearly every year in recent memory has experienced a seasonal labour shortage, to the dismay of growers." (Chumko, 2019 26).

In March 2019, a new robotic apple harvester travelled to Aotearoa New Zealand from Silicon Valley. The harvester was branded as a "world's first" by national and international newspapers, and videos showing the harvester slowly vacuuming apples from a row of slender apple trees along a trellis circulated widely through popular agricultural media. Similar articles were published in the Guardian about automated raspberry pickers, where the authors speculated that the robot would outpace human workers in the future. At the moment, the raspberry picker, like the apple harvester, was slow and awkward, riddled with technical challenges that would make it currently inappropriate for widescale use.

When we began doing research around perceptions and uses of new technologies in apple orchards, it inadvertently coincided with the trial of the robotic harvester in New Zealand, and so it was salient in the minds of our research participants, even though it was not actually the focal point of our research. Nonetheless, it made discussions about more abstract technological development prospects and processes more concrete, and the experiences of our participants seemingly more easily explained. Some of the concreteness was literally grounded and embodied, with participants noting how incredibly loud the harvester was, and some remarking that they simply would be unable to run the machine for the sake of their neighbours and communities. Others remarked on how slowly it ran, or how it struggled with any kind of variation.

There were also ways that seeing the machine in operation influenced how the farmers we interviewed speculated about the future. Many suggested that the machine was not practical in its current state, remarking that it would be a decade before the machine would be usable in any commercial orchard. Some saw a transition in the nearer future, while others thought that it would never come. Regardless, the majority of growers we spoke to saw new artificially intelligent (AI) robotic technologies as playing a role in the future of the apple industry, and to varying degrees they were engaging in preparatory actions that would shape that future and its form. In some cases, the actions of growers reflected a clear vision about what farms of the future would look like. These visions often mirrored popular imaginaries of fully automated

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production systems, with drastically reduced human intervention. With this clear vision in mind, orchards could either adopt or reject this model in practice. Others were reticent about this singular future, and engaged in practices that would enhance their ability to make strategic decisions about automation technologies as they emerged. In this paper, we consider these types of practices in the context of everyday, lived anticipation.

This article considers how the prospect of new technologies influences the strategies and practices being adopted in apple orchards. It takes an assemblage approach, where we focus on the ways that humans and non-humans—the latter category broadly including everything from plants and technologies, to rules and media discourse—become worked together and hang together to create a particular sphere of reality (see DeLanda 2016; McFarlane and Anderson, 2011). We use this to further ideas around anticipation in the context of agri-food technology. While anticipation commonly refers to speculative forecasts about the future, we use the assemblage approach to attend the material practices involved in this future-making process. Taking an assemblage approach leads to the following assumptions: 1) anticipation maps future expectations onto present realities through their material enactments; 2) practices and strategies for the future are constrained by material realities; and 3) narratives that explain the logic behind those practices and strategies arise concurrently with their possibility. These underlying assumptions highlight the central role of producers' practical and material worlds in shaping their intentions, explanations, and visions for the future. In this way, the farm is not a passive backdrop to the agency of the farmer, but—in line with Ika Darnhofer's (2020) work on "process-relational" perspectives—the farm *participates* in enabling and constraining action while shaping what kinds of worlds become imagined . As we elaborate in the next section, this approach can add to scholarship on anticipation and expectations related to technology and change, particularly as it is elaborated within new work on responsible research and innovation (see Owen et al., 2012; Burget et al., 2017) and anticipatory governance (Karinen and Guston 2009; Guston 2014). At the same time, this approach can add to our understanding of uncertainty, agency, and social power in the context of technological change and democracy.

We look at three different things being assembled in apple orchards in relation to anticipation: landscapes, work, and institutions. By looking at these three components of farm practice, we can see patterns emerging in how anticipation is exercised in ways that cohere with the existing material and symbolic operation of the farm. As we elaborate in the following two sections, an assemblage approach enables us to look at ongoing everyday practices that both perform tasks and reproduce the conditions through which actions take place. The approach also provides an opportunity to identify how materials and practices shape the democratic possibilities that can be realized in anticipation. In this research, patterns in assembling landscapes, work, and institutions were roughly categorized into three practical styles: technocratic, deliberative, and isolated. The contours of these categories are hinted at in our results section and elaborated in the discussion, where we pay particular attention to the implications of anticipatory assembling for more democratic forms of technology governance. Through observing how producers are enabled or constrained in ways that shape their sense of agency, we identify processes that may undermine producers' abilities to steer technological change in ways that ensure a robotic future is as deliberative and democratic as possible.

1.1. Anticipating new technology

Images of an automated agricultural future emerge textually from time to time in major news outlets, describing a farm devoid of human presence. To name a few from a vast pool, headlines include: "'We'll have space bots with lasers, killing plants': the rise of the robot farmer" (Harris 2018, *The Guardian*), "In the future, will farming be fully automated?" (Belton 2016, *BBC News*), and "The Age of Robot Farmers" (Seabrook 2020, *The New Yorker*). Many of these articles gesture to a particular kind of food future. They may even link this future to pressing global circumstances, like reduced access to migrant farm workers and reduced access to water and land. Few of these articles frame this future as including any farm diversity or impediments to the adoption of robotics; this future is depicted as inevitable, singular in its character, and without any kind of process unfolding that would shape how automation gets incorporated into farms over time. It would seem that we will simply jump from an industry with significant human input to one without any, just about overnight, as the last vestiges of necessary human involvement in agriculture—decision-making—are replaced by big data and artificial intelligence. As Fairbairn and Guthman (2020) note, the recent Covid-19 pandemic is likely to increase the interest in robotics and automation exponentially, as promissory fantasies of abundant food supplies and impenetrable production security falls on increasingly eager ears.

This imagery does more than simply project a particular kind of agricultural vision, but is likely to influence the social and political processes involved in the unfolding history of agricultural technology. Indeed, this research aims to show that some human actors at the centre of this change—farmers—do see the introduction of robotics in ways that align with the popular narratives described in these articles: as inevitable and objective in their effects as they integrate organically into the existing agricultural system. However, these are by no means the majority of perspectives. Many farmers see robotics as having effects that are dependent on global economic dynamics and ecological factors that are not fated, but rather socially-produced, and that shape the suitability of particular kinds of robotics for farms and change the roles of human labour on the farm.

By exploring the ways that farmers anticipate new agricultural robotics and their material effects, we contribute to a large body of work that has described the impacts of technology on farmer communities and global food systems (McMichael 1994; Fitzgerald 2008; Jarosz 2012; Holt-Giménez and Altieri 2013; Carolan 2020). The plow in the United States has been linked to the American dust bowl and the great depression (Worster 2004). Fitzgerald has well documented the industrial character of farming that emerged as a result of mechanization and policy in *Every Farm a Factory* (2008). Describing particular emergent features of modern agriculture, Van Der Ploeg (2010) has discussed the role of agricultural industrialization, along with market liberalization and imperialism, in perpetuating rapid price fluctuations and food crises. These are but a few of the works that document the negative social outcomes of technology adoption resulting from the capitalist global economies in which they are situated.

More recently, scholars have described how the effects of new digital technologies may both extend and diverge from these historical patterns, due to the unique capacities of big data, artificial intelligence, "smart farming," or "digital agriculture" to essentially make decisions (see the review by Klerkx et al., 2019). Combined with robotics, these computational processes do gesture towards the possibility of full automation, and at the very least, steps towards farm automation in a way that differs from simply mechanization. In this way, new technologies can distinctly influence practical autonomy and control of farm practices (Carolan, 2018); shape the types of knowledge necessary for agricultural practice (Miles, 2019; Carolan, 2017) with implications for the composition of farm work (Butler and Holloway 2016; Vik et al., 2019); and raise a range of concerns about privacy, ethics, and democratic governance (see Bronson 2018; 2019; Jakku et al., 2019).

While maintaining a critical perspective in light of historical patterns of technology adoption on food systems, we can also see that technologies can have different effects on society as a result of their design, ownership, or form of social development and introduction (Klerkx and Rose 2020; Fielke et al., 2019). Ongoing work considers whether particular agricultural technologies—and the style with which they are developed and adopted—may break with or combat historical patterns of accumulation, imperialism, and inequality. Some have considered how technologies may create more diversity in production, facilitating more collaborative relationships while maintaining mid-sized farms (Legun 2015; Comi 2019). Other work considers how social empowerment might come from direct engagement with technologies—an act which might combat its restrictive social forms. Carolan discusses how farmers may resist closed-design forms of precision technology and reclaim control through collective knowledge networks like FarmHack (Carolan 2017). Higgins et al. (2017) have discussed how farmers may engage with *tinkering* in precision agriculture to rework limiting commercial features. Along these lines, Carolan (2018) has suggested that we focus on socio-technical arrangements and how they contribute to, or restrict, producer sovereignty. These arguments by Higgins et al. (2017) and Carolan (2017, 2018) highlight that the possible effects of technology relate to control over *how they are used*. This ability to determine how technologies are used is shaped by a number of aspects: the design of the technology (the degree to which people can manipulate it to purpose); farmers' abilities to negotiate processes of adoption (the degree to which adoption is voluntary); and the degree to which farmers have control over other aspects of the farming system that shape the effects of technology (their ability to influence the access to technology and effects on labour relations, for example).

Governance power in the development of technology has been elaborated in scholarship on responsible research and innovation (RRI) (Owen et al., 2012; Von Schomberg 2011, 2013; Stahl et al., 2017), and is increasingly used in the context of agricultural technologies (see Eastwood et al., 2019; Bronson 2018; 2019; Gremmen et al., 2019). According to Von Schomberg (2011: xx), "Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other." Proponents of RRI suggest these forms of "mutual responsiveness" operate at the beginning of the research process, during the initial use of new technologies, and when evaluating the outcomes of technologies and their benefits. Owen et al. (2012) discuss this as "democratising the governance of intent," "institutionalising responsiveness," and "reframing responsibility." The RRI framework has since been elaborated within the European Union's (EU's) European Commission, suggesting that EU-funded projects must include public participation and deliberative social processes in any technology developments (See EU, 2020). Applying RRI to the case of digital agriculture, Bronson (2018) has suggested extending and including a broad range of 'rights holders' (end users and citizens) in governance decisions around new agricultural technologies.

One thread developed within the RRI framework is a focus on anticipation (Stilgoe et al., 2013). Anticipation is collaborative and involves trying to better understand the potential effects of technology through empirical insights, reflection, and discussions among diverse groups. It also includes open and honest discussions around the desired futures associated with a technology project (Stilgoe et al., 2013). Within the RRI framework, anticipation is oriented towards creating the discursive context to enable democratic decision-making processes regarding technologies, and is always integrated with inclusion, responsiveness, and reflexivity. This basic premise is also elaborated in related work on anticipatory governance, which aims at creating the governance conditions to support people in managing technologies as they emerge in real time (Guston, 2014).

A focus on governance capacities is a fundamental aspect of anticipation, and it also speaks to a particular challenge in the role of anticipation. This focus on governance ensures that technological development processes are not simply rearticulating, or reinforcing, current speculative tropes and fantasies. In the case of agricultural technology adoption, and particularly with relation to automation in agriculture, there exists a substantial cultural media describing futuristic farms. As a result, anticipatory discussions influenced by these dominant imaginaries risk discursively cementing a particular, singular future and its supposed inevitability. Along these lines, in relation to nanotechnology, Nordmann (2007: 31) suggests that new efforts to include publics in anticipatory discussions can signal an engagement in speculative ethics, which "constructs and validates an incredible future which it only then proceeds to endorse or critique." In doing so, he also suggests that futuristic fictions get articulated as possible technical developments, detracting attention from current technologies and their effects. If public engagement processes in technical development simply draw up possible futures and ask participants to discuss whether such a future is desirable, they may actually curtail efforts to genuinely involve publics in technological processes.

A focus on governance capacities can be seen as one method for firmly situating anticipation as a politics in the present, performed through an engagement with the future (Schneider and Lösch 2019). Instead of considering the process of anticipation as an exercise in imagining the future and mapping a path towards it, Nordmann (2014: 91, original emphasis) suggests exercises in anticipation position "the future as a markedly different world that serves as the measure or *telos* of the currently known world, embodying a conception of the good life that orients our actions today without any hint at a distinct or indistinct causal pathway that can lead from here to there, from now to then." Indeed, planning a pathway to a future and simply developing a recipe for its management can be ultimately disempowering. Taking a materialist assemblage approach, Groves (2017) describes how anticipatory planning for energy in the UK mobilized expertise and socio-technical apparatuses to create a highly quantified and utilitarian vision of future energy management, making that future abstract and empty.

Following Groves (2017), we use an assemblage approach to think about anticipation as a current, situated exercise in the reflection *and* management of potential technological futures, and as such, we also consider anticipation to be a material politics of the present. Unlike Groves, we do not look at processes of anticipation for the purposes of strategic planning by experts, but rather through the everyday decisions of farmers. In doing so, we aim to shift focus away from expert processes, and away from these kinds of interventions that can that empty the future through the design of an abstract risk management or auditing systems. Instead, we focus on anticipation as an everyday exercise that infuses the future with possibility through material changes to the present, albeit in a way that is engaged with the material and political conditions created by the past. Attending to the ongoing anticipatory engagement of farmers in their material lives helps us focus on the everyday as politically meaningful, and it highlights the ways that the democratic possibilities associated with anticipation are bound up with practical and material realities.

In this research, we add to the literature critiquing a superficial engagement with anticipation, approaching it as merely an exercise in speculative forecasts about the future. We emphasise that narratives ignoring material practices of anticipation risk reproducing visions of change that are devoid of human agency, reducing possibilities for genuine democratic engagement with technology. We argue that anticipation is a practical, situated activity exercised in the present, where expectations for the future are in dialogue and co-evolving with one's current capacity to engage in the management of technologies. In other words, people will practice strategies that they see aligning with future technological expectations in their industry, but will also change those future expectations depending on what they presently experience as being practically feasible and desirable. By taking an assemblage approach, we are able to see how orchardists are *assembling in anticipation*. That is, they are organizing their orchards with an eye to a possible technological future. In doing so, they are also influencing that future and their ability to informatively steer it.

1.2. *Assembling in anticipation*

An assemblage approach draws our attention to the ways in which ideas about the future are exercised in the present. Assemblages are networks of heterogeneous elements—ideas, materials, plants, technologies, people—that enable actions and create the practical worlds we inhabit (see DeLanda 2016; McFarlane and Anderson, 2011). *Assembling* (or sometimes *assemblying*) refers to ongoing processes of coordination through which elements are incorporated, retained, or removed from an assemblage. Non-humans are engaged in processes of assembling—e.g., developing and retaining symbiotic relationships with a host of companions. Humans are also constantly assembling—e.g., holding together or adapting to the worlds around them in ways that enable future action. The foundational role of non-humans in the shaping the world and influencing human capacities for action has led them to be described as *vibrant matter* (Bennett 2010), the notion of vibrancy capturing their animacy, while the *relational materiality* underlying these approached has been elaborated by Goodman (2001) in the context of agri-food studies and nature.

The assemblage approach has been instrumental in describing how the practical worlds that shape actions and ideas are built. Examples of assembling can be found in the work of Li (2014), who describes how a particular, novel assemblage formed around land transformed it into an object for financial investment. Winder and Le Heron (2017) also offer an assemblage approach to better understand how marine 'Blue Economies' are built. Nel (2017) has used an assemblage approach to understand the virtual, material, and territorial dimensions of new forms of carbon forestry. These works clarify the ways spatial, material, technological, social, and institutional elements are brought together to create a sphere of action with new possibilities, tendencies, and logics.

An assemblage approach can further our understanding of anticipation as an exercise in the present. Taking the assemblage approach implies that people's visions for the future, and how those visions materialize in reality, are grounded practically in an existing, situated context. In other words, people's expectations of *how* they will be influenced by new technologies are related to both their current practical engagement with the world, the underlying assumptions about how that world operates, and the resulting pathways through which change is perceived as possible. An assemblage approach to anticipation in technology draws our attention to three important aspects influencing ideas and visions related to new technologies: 1) existing material realities and the practices they enable; 2) the capacities and motivations people have to change those realities; and 3) the non-human forces that exist and influence capacities for action.

By taking an assemblage approach, we can also interrogate how agency and power operate in anticipatory practices. We can examine both what producers imagine they can do, and how they exercise those imaginations in current practices. As we discuss in our results sections, our research suggests that for some growers, a particular type of automated future was inevitable and fated, regardless of human action. Moreover, farmers' abilities to envision their own farm as a part of that future depended on their material resources. The implications of these findings for participatory approaches to innovation governance will be elaborated in the discussion section, but suffice it to say here, we would not expect the determinism associated with these material conditions to enhance the democratic governance of technology. Other growers engaged in a form of anticipatory assembling that would expand their ability to make informed decisions about robotics in the future, and they placed themselves and their work as characters in the story of robotics.

In this paper, we look at three types of things being assembled in apple orchards: landscapes, work, and institutions. Each of these are, in fact, clusters of things, or small assemblages themselves. Landscapes are clusters of ecological and technical elements built into the material structure of the farm. For apple orchards, landscapes include things like trees, irrigation systems, trellis systems, soil, and space. Work includes knowledge systems that shape the kind of information necessary to make decisions, and relatedly, the kind of labour and skills necessary to keep the orchard producing apples in a way that maintains the economic viability of the orchard. Lastly, the institutional environment is the social structure that organizes and shapes the relationships between apple producers. The institutional environment shapes where people think they can exert influence to change the conditions of production. The very nature of apple production involves assembling these elements together in everyday practice. Thus, we are not implying that these elements are brought together as a response to the prospect of new technologies. Instead, we argue that new robotics being developed for agriculture can influence how these elements are assembled together and, in turn, that the particular assemblage of these elements on a farm shapes how farmers anticipate the future effects of new robotic technologies on their orchards. Framed in another way, anticipation is the way that robotic technologies become a discursive idea, coherently networked into the existing orchard assemblage and shaping other material assemblage elements.

Following a short section on methodology, we will move into our result section. In this section, we will illustrate the landscapes, work, and institutional environments being assembled by our study participants, highlighting some overarching characteristics patterning these assemblages. We describe these overarching characteristics as technocratic, deliberative, and isolated tendencies. Our result are followed by a discussion section. Within this section, we consider how technocratic and isolated tendencies both frame technological evolution as something uniform, inevitable, and devoid of human intention or intervention. In many ways, this echoes popular depictions of robotics in media, which seem to pre-emptively situate robotics as a kind of uncontrollable future force. However, as we also discuss, many of the growers we spoke to adopted a much more deliberative approach that considers robotics to have a more variable and malleable role in the future of agriculture.

1.3. Case study and methods

This research is part of a large, trans-disciplinary collaborative design (co-design) project based in Aotearoa New Zealand. Over the course of five years, the project aims to develop robotics with AI capacity to support and potentially automate tasks on apple orchards, wine vineyards, and blueberry farms. While much of the project is dedicated to engineering and computer vision tasks associated with developing physical technology, the project involves considerable input and participation from apple, grape, and blueberry farmers—who guided the selection of technological goals at the outset of the project—and who are involved with field trials of the technologies. A significant part of the project is also dedicated to a social science team which aims to better understand the social implications of these technologies as they are being developed through the co-design process. This research is part of that effort, which also involves work on the social and cultural dynamics of the co-design process, indigenous Māori business and community responses to the introduction of new agricultural technologies, as well as project impacts on things like workers, technical information, and industry adoption. Ethics approval for this research was secured through the University of Otago Human Ethics Committee.

The research on anticipation presented in this paper serves to expand our understanding of the social environment that this co-design process is entering into. It also serves as a baseline so that we can better understand project outcomes, and technological trajectories when follow-up interviews are conducted during the last phase of the project.

To simplify the presentation of findings in this paper, we have limited our discussion to the apple industry. We conducted 22 interviews in June, September and December of 2019, primarily with orchard managers. Our criteria for inclusion was that we interviewed people who had decision-making capacity regarding technology on their farms, and tried to talk to those who managed or owned orchards of varying sizes and ownership compositions. We primarily set up interviews with the support of a project team member who was a consultant within the industry. We asked for suggestions and introductions for a diverse range of producers in the apple industry. We also asked interviewees for referrals.

The interviews were open-ended, and asked interviewees a range of questions about their operation, changes in the industry overall, the technologies they used and expected to use in the future, and their relationships to those working on their orchard. We focused considerably in our probing questions about how things were done and why, but the interviews were conversational and largely led by participants, so we could get a sense of those topics that seemed most salient to understanding technology in agriculture. Our analysis of interviews was highly iterative with the analytic narrative starting to take shape during the interviews, but developing coherence and clarity through constantly revisiting the data and rethinking the interpretation. This process followed a grounded theory approach, where we entered the research process with background knowledge and expertise, but developed our explanatory theory through the research and from the resulting data (see Charmaz, 2014).

In New Zealand, there are varying economic structures of orchards: some are fully owned and operated by a corporation who employs an orchard manager and markets all the apples; some are run largely independently and may be a family-run business, but are contracted to supply a corporation and are heavily integrated into that corporation; some are large and family-run, and supply a marketing company that does not own orchards; some are family-run and operate their own marketing business; and some are family-run and supply corporations, are independent marketers, and engage in direct sales. This heterogeneous structure has much to do with the de-regulation of the industry in 2000, where the single-desk entity marketing all New Zealand apples was divvied up to suppliers according to their volume of supply, and was eventually incorporated into the marketing arm of the largest NZ apple producer, Turners and Growers (T&G). New corporations also quickly emerged in New Zealand to market apples. Some family farms remained and developed their own marketing arm, some expanded, and many went out of business (see Legun 2018). Apple prices were low following deregulation, but have been so high over the past five years that many who remained in the industry are generating enough profit to be sustainable, regardless of size or the degree to which they have invested in their orchard. New Zealand has, compared to other country averages, the most high-yielding orchards in the world, and some of the most valuable apples—New Zealand is frequently ranked first in the "International Competitiveness Rankings" of the major industry publication, the Belrose World Apple Review (Belrose 2017: 156).

Due to the diversity of their operations, the New Zealand apple industry provides a rich context for exploring how agricultural actors orient to new technologies. Some producers have significant resources to invest in and prepare for new technologies. Others are more economically restricted, though apple prices are high enough that they currently do not need to scramble to increase efficiency. The one factor that all growers identified as a potential motivation for increased robotics was the future availability of agricultural workers. New Zealand apple producers depend heavily on seasonal workers, largely from the Pacific Islands, who enter the country through a guest-worker scheme. The number of guest-workers allowed into the country depend entirely on allowances afforded by the federal government. During our interviews, growers shared varying interpretations of the social sustainability of the scheme in the distant future. However, with the onset of the global Covid-19 pandemic, and associated border closures in New Zealand, the sustainability of this scheme will be something farmers will be forced to recon with much earlier than they had expected.

2. Results

2.1. Landscapes

Landscapes in New Zealand apple orchards vary greatly, so much so that one might not believe that two different orchards are producing the same crop. One of the main differences relates to the size of the trees grown. Dwarfing rootstocks, increasingly popular in apple production globally, keep trees small and vine-like, so they can be grown on a trellis. These trees are often trained to be flat against the trellis, resulting in what growers call a "two-dimensional system." The aim of these systems has historically been to increase light penetration to apples, but by no means is this method accepted universally as the best training system. There are a lot of growing systems that rely on bigger trees with a fuller canopy. As we will described later, some growers saw these fuller canopy options as being ideal for particular ecological conditions or for more common varieties of apples that have less rigid aesthetic parameters for marketing. Two-dimensional systems are adopted with a variety of intentions and are by no means a tree architecture linked solely to robotics (Legun 2015). However, their adoption in New Zealand currently takes place within a specific complex of motives and recommendations: they are viewed as the system able to most easily integrate with robotics for automation.

It is no coincidence, then, that popular media videos of the robotic apple harvester trialed in New Zealand documented the machine travelling down uniform, well-manicured, two-dimensional rows. New machines for automation in picking, pruning, and potentially other orchard tasks, are likely to initially be developed for these orchard systems as they present the machines with simple tasks: travelling in a relatively straight line and scanning a relatively flat plane for apples. With the occlusion caused by leaves within more simplified two-dimensional systems already challenging robots' abilities to find apples, the task of navigating a more complicated plane of branches and foliage presents these new technologies with an infinitely more difficult task. Here we can begin to notice how farmers' material entanglements within their particular landscapes—in this case with trees, tree spacing, trellises, etc.—affect their desire or ability to assemble their farms in ways which might align with the needs of a robot. Thus, many growers were grappling with the material needs of yet-to-be developed robot as they engaged in the planting or replanting of their orchard. For example, Dan, an Operations Manager in a large corporate-owned orchard, identified new robotics as the main motivation for choosing a two-dimensional system for his recently planted orchard: "Obviously" he suggested, "the robot is what this particular place is designed for the harvesting robot. I guess mechanization for us as a company or a business is vital moving forward."

Dan's example highlights a particular motivation and ability to organize non-human materials—e.g. apple trees—to align with the anticipated needs of a robot. However, other growers were dabbling in different orchard styles, as a form of experimentation for technologies that they saw as potentially emerging in the future. Moreover, many suggested that even if these technologies did become available, there would be a variety of factors that would influence their adoption. One of these influencing factors was growers' actual experiences planting and working within these new growing systems. For example, Hugh, who worked for a large orchard that was independent but supplied a major corporate, said:

> We predominantly grow a spindle-bush tree [a three-dimensional tree on semi-dwarfing rootstocks]. … But what we're doing at the moment is we've been involved with T&G and their robotic future. We've actually set up a small block of trial robotic-harvested orchard. It's not a large block; it's about .7 of a hectare. They have to be a single plain; they can't be a bushy tree, so the fruit is exposed to the machine … So we grew some now to get it to the point where, okay, if we wanted to either transfer our orchard over to that system or plant more, we're ready to go. I still won't be going out and planting it tomorrow.

When asked to explain further, Hugh suggested that they would consider expanding their two-dimensional plantings and orient more to the prospect of incorporating robots depending on labour policies that shape access to seasonal workers. They would also take into account the cost effectiveness of new robotics, which would include accounting for levels of apple production in these new growing systems and the cost of transitioning to these systems.

Flynn, the operator of a large family orchard, described his experience with similar kinds of experimental landscapes. His reflections suggested that corporate governance influenced plantings, but that growers were also "tinkering" with the specific materialities of their orchard systems in a way that could accommodate the needs of a robot:

> T&G, up north and probably Mr Apple, but Mr Apple … a lot of their planting systems still don't cater for picking machines. We've still got big chunks that don't cater for picking machines so until it becomes really driven one way or the other, I think you'll still see people plant their way, 'cause again, they're getting lots of apples to market. When you've got 1600 apples on one tree it's more simplistic than trying to get that over five or ten trees. But there's pros and cons either way. Smaller trees are a little bit easier for the staff to work a little bit more consistent. So yeah, growing styles are still hotly debated about which is more beneficial and which is best and you'll see most growers are tinkering. I say tinkering cos they're not going to shift everything across until they can see the benefit of one way or the other.

Similarly, some orchardists also expressed anxiety about transitioning their orchard to a denser system without being certain about future robotics available. For example, Terry had been planting a high density system that had only 2 m between rows, which seemed like it may be too narrow for new harvesting technologies currently being developed:

> Well the mechanical harvesting for me was a scary one because I personally haven't seen any harvesters that fit down a two metre row … but I've been told that they are around. But I think for us we just want the best out of the land as well, so we're looking at whatever robots there are … yeah, I don't really know what I'm trying to get at here. We're in a little bit of limbo at the moment. We're pretty sure this is the way to go, and I think we just need another year or two under our belt to see what technology is coming to actually make an informed decision.

Terry's example highlights just some of the complex material relations that must be considered when assembling landscapes in anticipation of new technologies. For example, trees need to be planted in particular ways for technologies—from tractors, to mowers, to robots—to be able to complete their intended tasks in the most efficient way possible. If a farmer made a decision to plant trees according to a non-robot-centered logic, this might result in row spaces that are too narrow or tree structures that are too complex for a robot to handle. And as Terry clearly notes, uncertainties on the exact needs of a yet-to-be-built robot can put farmers—who are already working within and attempting to coordinate a number of complex material relations—into a state of limbo.

Thinking through the situated material constraints of their orchards, some of the orchardists we interviewed argued that two-dimensional systems were simply not appropriate for their farm given their soil, topography, or the economic strategy they employed. For example, Harvey, who owned and operated a large family-owned orchard, emphasized that New Zealand soils were inappropriate for robotics because they were too rich, and the tree would tend towards becoming too bushy (i.e., it would have too much "vigour"):

> … if you try to contain a tree in a space, in theory yes because the root system is competing with the one next door vigour will be limited, but what people are sort of losing sight of is, the fact that the soils are so rich that the roots will travel downwards and they'll keep going and going. And, so they tap into moisture down there and they're just really enjoying themselves and they just keep growing … It's like a fire; once you open the door you get more oxygen. With cutting a tree, the more you try to open the tree up, the more it's going to respond.

Importantly, while Harvey saw two-dimensional systems as ecologically inappropriate for much of the New Zealand context, he was also enthusiastic about the prospect of adopting new robotic technologies in the future, but believed that they would have to be able to navigate a three-dimensional planting system in order to work. Again, these insights offer important clues into the complex materiality of landscapes that orchardists are forced to consider when assembling in anticipation. That is, while there may be some aspects of landscape assembling—such as tree spacing—which farmers may be able to control, there are other aspects that might disrupt attempts to coordinate an orchard to suit the needs of a robot or other new technologies—e.g., soil fertility, soil type, a tree's vigour, among countless others. Harvey's reflections also open-up important questions into how much landscapes need to be tailored to the needs of robots, or whether robots can be tailored to meet the needs of trees and farmers.

Thinking through their own complex material constraints in tailoring their orchards to the needs of robots, some of the orchardists we interviewed suggested that they wouldn't make their orchard "robot-ready" because their orchard would not be appropriate for the types of machinery being developed:

> Our ground conditions; Some of my rows which are 300 m long, I've got five different soil types, some of these soil types aren't designed for heavy machinery so that creates issues. We're still going to need to pick, I still think, probably 70 percent of my crop by hand. (Flynn, operator, large family orchard)

> I haven't got my head around the tall spindle, why move onto something else? And especially like what they call the FOPS system where the trees are pulled over … it's not proven. And the 2D, I think it's got huge potential for robotics and stuff like that down the track, but we're on the hills, we're real steep and to have machines on hills, it's not quite as straight forward. (Tom, orchard manager, large family orchard)

Beyond the material constraints of multiple soil types and steep hills, there were other orchardist for whom transitioning to robot-ready systems was not seen as feasible because it was not a part of their economic strategy, which involved excelling at producing standard apple varieties at a low overall cost:

> … getting down to the two-metre stuff is not something that we've really considered at all …. Our last redevelopment we grafted onto an existing planting … I must admit it comes back to sort of getting some crop off them quickly. Rather than ripping everything out and starting again, if you've got trees that produce okay, but it's just not a variety that pays … I mean, we've got our own graft wood and things like that to be able to [reuse the old roots]. (Hamish, manager, mid-sized family orchard)

As the above examples highlight, some growers were attempting to coordinate the complex materiality of their landscapes to account for the needs of robots. This happened through a wholesale attempt to be completely "robot-ready" through two-dimensional plantings, as well as through some experimentation on their orchard with different growing systems that they saw as likely to accommodate new robotics. For those adopting an experimental strategy, it was clear that they were assembling their orchard landscape in anticipation. That is, they were adopting techniques that would best enable them to make informed decisions about the adoption of robotics based on both social and ecological factors. Those who chose not to change their landscape to accommodate robotics seemed to have a clear sense of how the materiality of their landscapes related to new robotics they expected to see in the future. In cases where there was hesitancy, the complex, situated materiality of orchard landscapes—soil type, steep hills, etc.—and current processes of coordination—row spacing based on tractors or mowers, current economic strategies, ect.—were recognized as complicating efforts to coordinate an orchard to meet the needs of a robot. Harvey, for example, emphasized that these technologies would have to fit with the existing best growing practices, which he believed would mean accommodating a more variable and complex apple tree. Others, as we discuss later in the paper, saw their orchard as inappropriate for mechanization. As a result, they felt inherently excluded from the world of robotic development, unlikely to ever adopt new robotic technologies. They envisioned their eventual disappearance from farming as stemming from their inability to compete in an inevitable robotic future.

2.2. Work

Along with its physical qualities, two-dimensional growing systems are related to a different way of orienting to orchard space, knowledge, and decision-making, all of which have implications for the kinds of work that happen in an orchard. When trees are grown in two-dimensional systems, the orchard becomes homogenous and abstract such that actions are not carried out per tree, but rather per unit of space. Dan, an Operations Manager in a large corporate-owned orchard, explained:

> Everything is calculated on essentially a linear metre rather than kgs per tree, or x per branch. The calculations for this are, I suppose, a lot easier to calculate … So, I can give people two instructions and I'll get a high quality job, after what I want, because everything is the same.

Within our interview, Dan also suggested that this type of calculation meant that workers with no agricultural experience could easily perform the work. When asked whether they would still require high skilled workers to manage machinery, he suggested that it, too, would not require any significant farm knowledge: "… a lot of the stuff is pretty easy to operate" he said, "like, you don't need an IT degree to do it."

Indeed, many of the orchard managers we interviewed supported a two-dimensional system because they believed it would reduce the variable performance of orchard workers by standardizing the task. That is, it would reduce some of the complexity posed by the material entanglements—with humans and non-humans—orchardists were forced to grapple with as they attempted to coordinate activities on their orchards. For some, this standardization sounded like a classic deskilling narrative, whereby technology was introduced to simplify tasks to generate more standardized work, a reduction in the skills required for the work, and thus lower value for labour (see, for example, Fitzgerald 1993). In this case, deskilling narratives centered on a desire for more flexible labour sources and less time spent on training. In Dan's vision for the future, it would be relatively easy to develop a fully automated orchard, with very little human intervention—and, thus, the variability that comes with human work and the availability of human labourers. Others envisioned two-dimensional planting systems as necessary for better standardizing practices, so that future decisions for the orchard could be made more easily. For example, if the orchard had patches where a task had been performed differently, future activities like spraying or harvesting would also potentially have varying effects. Here, the increased standardization expected within two-dimensional systems was also expected to support farmers in better noticing, handling and making decisions regarding variations that might disrupt their farming practices.

Many of the farmers we interviewed saw the standardization of knowledge as increasingly important on most orchards. They also viewed the automation of some manual tasks as a likely part of a robotic future. However, many of these orchardists also insisted that growing apples necessarily involved creativity and skill in such a way that orchard work could not be completely usurped by robots. Hank, a manager at a family orchard, described this sentiment:

There's nothing like going into the orchard. So what we do in our peak summer, one of dad's roles now is he just goes round the orchard once every three or four days with his ute and a picker on the back and he just goes under some apple trees and picks the ground and just feels the dirt and still you can't replace that.

Furthermore, there were a number of farmers who saw physical presence and relevant knowledge as essential to running a successful orchard. As an example, Flynn discussed the labour structure and needs of the apple industry and lamented the cultural assumption that horticulture was a low-skilled job with little career opportunity: "We need people who've got thinking capacity. It's not just simple manual tasks, it's a whole lot more than that," he suggested. Later, when asked about the biggest influence on the profitability of an orchard, Flynn commented on the importance of workers physically and cognitively engaging with their material surroundings—in this case with apple trees—as an essential part of their work:

> Staff doing a really good job and actually being focused and showing the orchard love. So what I mean is, as well as having 20 staff, if they all walk down the rows and don't tell me about anything, it's not happening. They've got to be engaged, they've got to see things, they've got to know what's happening and be able to tell people early enough so that we can adapt […] or make changes. It's really important because for us; we've only got one shot. It's 12 months before there's another chance.

Here, Hank and Flynn highlight how creativity and embodied interaction is related in some way to one's ability to engage and relate with the specific materiality of an orchard's landscape. Thus, while processes of standardization articulated by Dan seem to involve a flattening of the complexity posed by human and non-human actors on orchards—individual trees, soil types, human workers—the process of creativity described by Hank, and processes of human – plant interaction described by Flynn, discursively constructs orchards as having a complex materiality and orchard work as involving an element of responsive tailoring. Our point in highlighting the materiality of these divergent experiences is not to normatively categorize them as good or bad. Instead, an attention to the materiality of these different work assemblages can deepen our understanding of how different materialities are incorporated and reproduced through orchardists' visions of work, with implications for what kinds of knowledge processing could be constructed artificially and programmed: there are different kinds of knowledge that can be attained through different forms of relating with landscapes, and these vary considerably between orchardists, and even within them over time and according to context.

There were other orchardists who explicitly linked skills and labour structure within the apple industry to the growth or corporates and large family farms. Arthur, an orchard manager, explained how this affects an orchardist's ability to assemble their work:

I think, slowly the orcharding is becoming more corporatized and there are more openings [for skilled work], because people can see it as a career path. Twenty-five years ago there were apple orchards owned by the owner, and then there's a few people working from underneath. You either owned an orchard, and the owner did most of the work; people had 20 acres or 40 acres, all those guys are gone now. There are sort of larger family operations, which are bordering on corporate, or you need managers and a lot more staff that's trained up. Not just some dude who turns up stoned and picks apples, that's what it used to be like. We actually have some people that are highly skilled, and slowly, we're starting to pay them a bit more I think.

Others considered current agricultural work to be either highly skilled or unskilled, in a way that seemed to imply that agricultural knowledge was largely embodied and difficult to abstract into rules, and agricultural tasks were organised around human bodies and impractical to replace with something else. John, an orchard manager of a medium-sized family orchard, described this viewpoint:

> If it's different plantings, and it's a different way that block has got to be sprayed in comparison to other blocks and things like that. I understand that myself, but I'm the one sitting on the sprayer doing it, and if you did too much and had to get somebody else, it can

sometimes be a bit confusing, I think, for other people. If you don't know and if I've got to spend all my time telling people and coaching them through it, I may as well be doing it myself … I know they talk about [robots] and the thought is that they can run 24/7 and all that sort of stuff, but people have got a lot of area to cover, and I still wonder how people are going to have all the machines to get the job done as quickly as they need to do it. I wouldn't think that that machine is going to be able to pick a two-hectare block in a day; but sometimes that's how quickly it needs to be picked, otherwise you're going to lose the maturity.

In exploring work assemblages, we can begin to see how the styles of work associated with orchards not only influenced how growers thought about workers, but whether they considered on-orchard human labour as an essential element for farming into the future.

2.3. Institutional environment

When explaining how they made decisions on their orchards, growers would refer to different institutional contexts in which they were situated. We consider institutions to be the formal and informal processes and rules that people orient their actions towards, but these also include material relations and physical infrastructures, including things like access to capital, markets, and plant varieties, as well as the placement of offices, determining the location and accessibility of decision-makers. This conceptualization of institutions is largely drawn from the new institutionalism literature (see Ingram and Clay 2000; Nee, 2005; Nee and Swedberg 2020). In this sense, it is also the social and political arena at a more macro level that growers narrate as the relevant field of action for making strategic choices about new technologies on their farms. In our research, we found three types of institutional environments: corporate, industrial, and individual.

For some farmers, their choices were strongly influenced by a corporate entity that owned and governed the orchard, and restricted their ability to make independent decisions. In these cases, farm managers would use language like, "we, as a company," or "the company has decided." This may reflect a more shared decision-making structure at a higher level in the company. However, it also resulted in farm managers narrating a somewhat disembodied force shaping on-farm activities. For example, Emily, an orchard manager on an orchard embedded within a large corporate, described how her decisions were influenced by the company:

The nature of corporates; there's not one person sitting in a room that you can just pop in and ask him, 'hey there's this really cool new technique I'd love to try, what do you think?' But I guess the flip side of that is they are very keen to be involved in any new technologies. So I guess the robotic harvester is a good example of that, you know, they're pretty invested in that. So the result of that is all the new plantings have to be harvestable by the robot in theory. Whether that's going to be ideal or not will be seen. Most small growers probably wouldn't go all in quite that much, but [the company] as a business have made that decision that everything they plant must have the potential to be robotically harvested.

Similarly, when asked why his large corporate-owned orchard had decided to quickly adopt new technology, Dan said:

I probably can't really answer that unless I'm sitting in the director's seat. With all their other divisions and businesses, they're very much the same as what we are here. They've always been leading edge when it comes to cropping and that type of thing. They always probably have the thing, [the idea], "if we've got the tech and it's working, we're going to be producing more tonnage per hectare, or yield, or retrievable fruit or whatever."

Other orchardists described dynamics in the industry as shaping their orchards and orchard decisions. That is, they saw themselves as individual decision-makers within a broader economic and political structure. These orchardists described conditions related to labour availability and skills development as influencing decisions around technology. They also viewed decisions around technology as being influenced by prices, consumer preferences, and, importantly, what other growers were doing. When asked why he participated in trials for new technologies, Samuel remarked on these considerations:

I'm just all for it. Anything that's going to actually help the industry get ahead. It's also because the 2D system that we have, there's other guys who are getting bigger plantings than us, but we probably learnt the most by doing it for the longest. … When we talked about deregulation before, what also happened is all the growers got quite insular because you were actually competing against your neighbour and that was such a shame. You lost a lot of what makes a grower a grower as far as a commonality. So, I've never been adverse to sharing information … it was anything that's going to be betterment for the industry. Obviously, we'll get a bit of benefit from it as well, but it's just being involved with new stuff, something different. It puts a spring in your step and that's what keeps you passionate about the rest of it if you can see things that are not probably necessarily for me, but for future growers, how are we going to make it easier for growers going ahead basically in a global market.

Flynn, the operator for a large family orchard, also discussed how decision making was situated within a dynamic complex of industry and ecological factors:

So, if [a consultant] comes to me with a new fandangled idea, I'd be like, okay tell me about it, tell me what it does, tell me what are my benefits going to be, what are my cost benefits going to be. And we might go and trial it in a hectare and give it a go, or we might wait and see what others do. It depends also what the owners of the business sort of believe as well. So some of it's us taking that to the owners and saying, 'Here's some of the benefits,' 'This is what I can really see value in,' 'I think this is where it's going to save us time, money or labour.' And them looking at that and then weighting that up and sitting down with the board and saying, 'I reckon we'll give it a go on this block to trial it.'

Others saw decisions on the orchard as primarily an individual activity, and refrained from paying too much attention to activities going on in the industry more broadly. Harvey, an owner-operator of a large family orchard, for example, said, "you can get carried away with trends and concepts that are prevalent for the day, but, sometimes you just can't get away from sticking to the basics." John, an orchard manager of a medium-sized family orchard, also attributed orchard activities as stemming from individual, as opposed to institutional, factors. During our interview, he speculated that the decision to pursue robotics, particularly at a time when the value of apples was so high, was largely a product of individual greed.

Overall, for all the farmers we interviewed, institutional environments had an effect on their sense of agency and their abilities to make decisions regarding anticipatory assembling. For farmers embedded within corporate structures, the corporation might provide a clear vision for a robotic future, removing farmer agency as they promote a specific recipe for assembling in anticipation. In other cases, farmers might have more agency and flexibility in assembling their orchards. However, this agency came with the responsibility of navigating complex institutional and ecological terrains to decide on assembling trajectories. Whether directly following industry-led trajectories or choosing to ignore industry trends, it was clear that farmers were forced to contend with a number of institutional processes and projections—including a dominant vision about an impending robotic future. Thus, orchardists were not only contending with the complexity of landscape and work assemblages, but their entanglements within complex institutional environments greatly influenced their own agency—or their perception of their agency—in assembling their orchards.

3. Discussion: technology and democracy

In the previous results sections, we have provided an overview of how situated landscape, work and institutional assemblages all play an important role in how farmers made decisions about assembling their orchards in anticipation for new technologies. Through observing to how orchardists were materially grappling with possible robotic futures within these interwoven assemblages, we identified three assembling tendencies: technocratic, deliberative and isolated (see Table 1). We argue that these tendencies influenced how orchardists viewed their own agency within their own complex landscape – work – institutional assemblages and, as a result, whether or not they viewed themselves as active agents able to shape a robotic future.

For the purposes of clarity, we have roughly divided the landscapes being assembled into three categories: robot-ready landscapes, experimental landscapes, and those constrained by ecological factors. To some degree, these are represented by the physical features of the landscapes themselves: trees planted in two-dimensional systems, trees planted in two- and three-dimensional systems, and trees that are significantly conditioned by soil type or topography, respectively. Landscape categories also refer to the narratives offered by growers about their orchards, through their explanations of how they were designed and why.

We have also divided work assemblages into three categories, with three kinds of associated knowledge systems. The first type of orchard has a work style where, hypothetically, all decisions could be made through abstract calculations. Here, the right information put into a calculation would lead to the right decision. In this context, work is simply performing a task and, hypothetically, you could have an orchard with no workers at all. Alternatively, others saw orchard work as including a level of creativity, with decisions requiring a kind of artful skill. In this case, a future orchard would include more skilled workers, who would guide farm practices and may even offer technological skills training to be able to engage with new robotics. Others saw work on the orchard as embodied: either highly skilled and intuitive, or requiring so much flexible manual labour that the rigidity of a robotic system would be necessarily inappropriate.

Growers also referred to different kinds of institutional assemblages that shaped how they could, or would, make decisions. For some, the corporations they were embedded within largely dictated what kinds of practices they would adopt. While in some cases farmers may have some input into the decision-making process, there was a collective business agenda that steered orchard activities. Others referred to a more dynamic industry environment, and their decisions were articulated as contingent possibilities: "if this, then we do that." They described watching what others in the industry did, and often referred to political and economic contexts as influencing their uptake of robotics. Others worked largely independently. Some of these were large family farms, and some were smaller farms who were likely less capitalized. These growers saw their own decisions as largely being independent, but they also saw the decisions of others as independent as well. This can be seen in the example of Hamish, who wondered whether the desire to adopt robotics was largely about greed.

These landscape, work, and institutional assemblages were not random. In our research, we found patterns that emerged in the types of landscapes, work, and institutional environments being assembled together. Unsurprisingly, we would say that these components fit together to be somewhat coherent. It would make sense that corporate structures would have the kinds of capital available to heavily invest in technologies themselves, and in redesigning orchards to be more robot-ready. It also makes sense that a robot-ready orchard would be structurally simple, such that the information needed to manage it could be abstract and rule-based, also simplifying agricultural work. Along these lines, we categorized this particular assembling tendency as "technocratic." Within this assembling tendency, the future would be determined by technology, and would not be shaped by human or ecological factors. That is, future outcomes would be almost predetermined by the natural unfolding of an inevitable trajectory towards greater automation. Here, questions of how this trajectory is realized had very little to do with farmers' own decisions, and more to do with the invisible hand of the market economy. For example, when asked whether they were interested in using more technology in the future, Hank replied:

> I think if we're not looking at either some way of automation, then I don't think businesses will exist … We kind of get forced into this, that at a certain point you've got to look at technology versus humans, and then the question is what do the humans do.

At the other end of the assembling spectrum, we noticed a more "isolated" assembling tendency. We struggled to find a term that would adequately capture the spirit of this type of assembling tendency, but the notion of isolated assembling denotes the ways that the landscapes are constrained by ecology or economic conditions; work is bifurcated through its embodied nature into highly skilled and highly unskilled work; and, the farm is envisioned as being a bit of an island in terms of decision-making. In this assembling tendency, robotics was likely to be seen as something irrelevant, or something to which these farms were excluded from and, therefore, unable to influence.

The differences between technocratic and isolated tendencies can be explained through a capitalization narrative. These two tendencies also reveal something about the material conditions that may curtail engaged anticipatory governance: growers with more capital will introduce more technology increasing their competitive advantage, while those who have smaller farms with less capital feel differently about technology because they are unlikely to have access. In this way, there is little agency, only a capacity to adopt a predetermined robotic future or a lack thereof. That is, we could highlight that these two kinds of assembling approaches share a commonality: they do not see anyone, and least of all themselves, as having the capacity or means to *shape* a robotic future or influence *how* technology is developed, adopted, or integrated into an industry. In other words, orchards are being assembled in ways that

Table 1
Landscapes, work and institutions as related to assembling tendencies.

Landscapes	Work	Institutions	Assembling tendency
Robot-ready	Unskilled	Corporate	Technocratic
Experimental	Creative	Industrial	Deliberative
Restricted	Bifurcated	Individual	Isolated

reflect, and reproduce, a lack of farmer agency in democratically shaping technological trajectories.

We also identified a large number of growers who were engaging in a more deliberative approach—an assembling tendency situated somewhere between technocratic and isolated approaches. Unlike farmers with technocratic or isolated assembling tendencies, farmers exhibiting deliberative assembling tendencies viewed themselves as creative agents within their farms and in shaping farming futures. Farmers with deliberative approaches assembled experimental landscapes, where robot-ready two-dimensional plots existed alongside three-dimensional systems. Work in these assemblages was considered to involve creativity and skill, with humans being essential actors in farming futures—-whether alongside robots or not. When it came to institutional environments, these farmers were industrious in how they navigated complex institutional, political and ecological terrains in order to map out their own trajectories. For these farmers, an industry transition toward robotics was something malleable; a process that they themselves would be involved in shaping. This process of shaping a robotic future was not abstract, but grounded within the particular materiality of orchardists' situated landscape – work – institutional assemblages. Observing this group, we can see the important role of an orchardist's sense of agency in determining how they might engage democratically in shaping a robotic future. It also highlights the dangers posed by a lack of perceived farmer agency: robotic futures designed without democratic engagement may lack integrity and robustness if they only attend to the needs of large corporates and robots, and not orchardists, apple trees, and the complex materiality of New Zealand's orchard landscapes.

4. Conclusion

Moving the apple industry toward a robotic future involves building a vision and forecasting future scenarios. Designing forecasts for technology transitions usually involves visioning possible future conditions, reflecting on their desirability, and anticipating farmer and industry adoption of new technologies. However, as interest in responsible and collaborative forms of technology development proliferates, it has become increasingly relevant to understand what is being forecasted and the space these forecasts leave for democratic engagement with the farmers intended to participate in technology transitions. In this paper we have borrowed from the assemblage approach to highlight how including farmers as active agents in technology transitions must involve recognizing the complex material entanglements within which anticipatory assembling takes place.

Our research illustrates that the ways farmers assembled their orchards varied greatly depending on the particular landscape, work, and institutional assemblages they were entangled within. In turn, we were able to notice how an orchardists' entanglement within their situated landscape – work – institutional assemblages affected their assembling tendencies, and the ways these tendencies reflected how they viewed themselves as participants within current stories of robotic futures: as actors participating in shaping these futures, or as passive objects with no say in how the story unfolds.

Proponents of responsible research and innovation argue that collaborative research is essential to creating technologies that are robust and useful to those people intended to use them. Because this type of research depends on the participation of farmers, a lack of perceived farmer agency within these processes poses a great threat to developing technologies that are able to work well within the complex landscape – work – institutional assemblages of orchardists intended to adopt new robotic technologies.

As sociologists responsible for researching community adoption of the technologies being developed within our project, this analysis has allowed us to identify those farmers whose perceived agency might preclude them from actively participating in co-design processes. In particular, we were able to identify farmers with technocratic and isolated tendencies, who tended to frame technological evolution as a singular, inevitable transition that could not be thwarted by human intervention. As a result, these farmers tended to view themselves as either needing to jump on a pre-determined bandwagon, or remain off, depending on how the particular forecast aligned or clashed with their situated landscape – work – institutional assemblage. Recognizing these tendencies as originating within farmers' particular assemblages has provided a further opportunity to discuss these different material entanglements with the engineers and computer scientists designing new technologies. Our hope is that discussions about differences in assemblages can support our team members in creating technologies that can better attend to the needs of a diverse range of farmers.

Ultimately, our engagement with the assemblage approach has allowed us to notice how efforts to use anticipation to expand participatory and democratic design and governance over technology is highly limited if agricultural actors see anticipation as a reflection of an inevitable historical process, and not a political action. This reflects a very neoliberal, and anti-political view of technology, where the only way to steer governance is through the farm purse. Attending to farmers' material engagements in landscape – work – institutional assemblages allows for noticing the specific material conditions that influence farmers' choices regarding on-farm adoption, and how it affects their perceived ability to influence technology development and adoption in the industry broadly. We believe an assemblage approach that attends to farmers' situated entanglements with landscapes, work and institutional environments provides important tools for scholars interested in exploring questions of anticipation through the lens of responsible research and innovation. In particular, this act of noticing can provide social scientists with further opportunities for better engaging farmers as partners in the responsible and collaborative design and adoption of new agricultural technologies.

Author statement

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References

Belton, P., 2016. "In the Future, Will Farming Be Fully Automated?" *BBC News*. Extracted July 22, 2020 from. https://www.bbc.com/news/business-38089984.
Belrose, 2017. World Apple Review. Belrose, Pullman, WA.
Bennett, J., 2010. Vibrant Matter: A Political Ecology of Things. Duke University Press.

Bronson, K., 2018. Smart farming: including rights holders for responsible agricultural innovation. Technology Innovation Management Review 8 (2), 7–14.
Bronson, K., 2019. Looking through a responsible innovation lens at uneven engagements with digital farming. NJAS - Wageningen J. Life Sci. 90, 100294.
Burget, M., Bardone, E., Pedaste, M., 2017. Definitions and conceptual dimensions of responsible research and innovation: a literature review. Sci. Eng. Ethics 23 (1), 1–19.
Butler, D., Holloway, L., 2016. Technology and restructuring the social field of dairy farming: hybrid capitals,'stockmanship'and automatic milking systems. Sociol. Rural. 56 (4), 513–530.
Carolan, M., 2017. Agro-digital governance and life itself: food politics at the intersection of code and affect. Sociol. Rural. 57, 816–835.
Carolan, M., 2018. 'Smart'farming techniques as political ontology: access, sovereignty and the performance of neoliberal and not-so-neoliberal worlds. Sociol. Rural. 58 (4), 745–764.
Carolan, M., 2020. Automated agrifood futures: robotics, labor and the distributive politics of digital agriculture. J. Peasant Stud. 47 (1), 184–207.
Chumko, A., 2019 March 26. World-first Robotic Apple Picker Could Curb Seasonal Labour Shortage. Stuff. Retrieved from. https://www.stuff.co.nz/business/farming/agribusiness/111545853/worldfirst-robotic-apple-picker-could-curb-seasonal-labour-shortage.
Comi, M., 2019. 'The right hybrid for every acre': assembling the social worlds of corn and soy seed-selling in conventional agricultural techniques. Sociol. Rural. 59 (1), 159–176.
Darnhofer, I., 2020. Farming from a process-relational perspective: making openings for change visible. Sociol. Rural. 60 (2), 505–528.
DeLanda, M., 2016. Assemblage Theory. Edinburgh University Press.
Eastwood, C., Klerkx, L., Ayre, M., Rue, B.D., 2019. Managing socio-ethical challenges in the development of smart farming: from a fragmented to a comprehensive approach for responsible research and innovation. J. Agric. Environ. Ethics 32 (5–6), 741–768.
EU, 2020. Responsible Research and Innovation. Horizon 2020. https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation. (Accessed 16 April 2020).
Fairbairn, M., Guthman, J., 2020. Agri-food Tech Discovers Silver Linings in the Pandemic. *Agriculture And Human Values*. Rapid Response Opinion).
Fielke, S.J., Garrard, R., Jakku, E., Fleming, A., Wiseman, L., Taylor, B.M., 2019. Conceptualising the DAIS: implications of the 'digitalisation of agricultural innovation systems' on technology and policy at multiple levels. NJAS - Wageningen J. Life Sci. 90, 100296.
Fitzgerald, D., 1993. Farmers deskilled: hybrid corn and farmers' work. Technol. Cult. 34 (2), 324–343.
Fitzgerald, D., 2008. Every Farm a Factory: the Industrial Ideal in American Agriculture. Yale University Press.
Goodman, D., 2001. Ontology matters: the relational materiality of nature and agro-food studies. Sociol. Rural. 41 (2), 182–200.
Gremmen, B., Blok, V., Bovenkerk, B., 2019. Responsible innovation for life: five challenges agriculture offers for responsible innovation in agriculture and food, and the necessity of an ethics of innovation. J. Agric. Environ. Ethics 32 (5–6), 673–679.
Groves, C., 2017. Emptying the future: on the environmental politics of anticipation. Futures 92, 29–38.
Guston, D.H., 2014. Understanding 'anticipatory governance'. Soc. Stud. Sci. 44 (2), 218–242.
Harris, J., 2018. "We'll Have Space Bots with Lasers, Killing Plants': the Rise of the Robot Farmer" *the Guardian* extracted July 22, 2020 from. https://www.theguardian.com/environment/2018/oct/20/space-robots-lasers-rise-robot-farmer.
Higgins, V., Bryant, M., Howell, A., Battersby, J., 2017. Ordering adoption: materiality, knowledge and farmer engagement with precision agriculture technologies. J. Rural Stud. 55, 193–202.
Holt-Giménez, E., Altieri, M.A., 2013. Agroecology, food sovereignty, and the new green revolution. Agroecology and sustainable Food systems 37 (1), 90–102.
Ingram, P., Clay, K., 2000. The choice-within-constraints new institutionalism and implications for sociology. Annu. Rev. Sociol. 26 (1), 525–546.
Jakku, E., Taylor, B., Fleming, A., Mason, C., Fielke, S., Sounness, C., Thorburn, P., 2019. "If they don't tell us what they do with it, why would we trust them?" Trust, transparency and benefit-sharing in Smart Farming. NJAS - Wageningen J. Life Sci. 90, 100285.
Jarosz, L., 2012. Growing inequality: agricultural revolutions and the political ecology of rural development. Int. J. Agric. Sustain. 10 (2), 192–199.
Karinen, R., Guston, D.H., 2009. Toward anticipatory governance: the experience with nanotechnology. In: Kaiser, M., Kurath, M., Maasen, S., Rehmann-Sutter, C. (Eds.), Governing Future Technologies. Sociology of the Sciences Yearbook, vol. 27. Springer, Dordrecht.
Klerkx, L., Rose, D., 2020. Dealing with the game-changing technologies of Agriculture 4.0: how do we manage diversity and responsibility in food system transition pathways? Global Food Security 24, 100347.
Klerkx, L., Jakku, E., Labarthe, P., 2019. A review of social science on digital agriculture, smart farming and agriculture 4.0: new contributions and a future research agenda. NJAS - Wageningen J. Life Sci. 90, 100315.
Kolowe, J., Davis, R., 2019. "Robocrop: World's First Raspberry-Picking Robot Set to Work" *the Guardian*. Extracted July 22, 2020 from. https://www.theguardian.com/technology/2019/may/26/world-first-fruit-picking-robot-set-to-work-artificial-intelligence-farming.
Legun, K., 2015. Tiny trees for trendy produce: dwarfing technologies as assemblage actors in orchard economies. Geoforum 65, 314–322.
Legun, K., 2018. Securing the future of apple production. In: Pawson, E. (Ed.), The New Biological Economy: How New Zealanders Are Creating Value from the Land. Auckland University Press.
Li, T.M., 2014. What is land? Assembling a resource for global investment. Trans. Inst. Br. Geogr. 39 (4), 589–602.
McFarlane, C., Anderson, B., 2011. Thinking with assemblage. Area 43 (2), 162–164.
McMichael, P. (Ed.), 1994. The Global Restructuring of Agro-Food Systems. Cornell University Press.
Miles, C., 2019. The combine will tell the truth: on precision agriculture and algorithmic rationality. Big Data & Society 6 (1).
Nee, V, 2005. The New Institutionalisms in Economics and Sociology. In: Smelser, N, Swedberg, R (Eds.), The Handbook of Economic Sociology. Princeton University Press, pp. 49–74.
Nee, V., Swedberg, R. (Eds.), 2020. The Economic Sociology of Capitalism. Princeton University Press.
Nel, A., 2017. Contested carbon: carbon forestry as a speculatively virtual, falteringly material and disputed territorial assemblage. Geoforum 81, 144–152.
Nordmann, A., 2007. If and then: a critique of speculative nanoethics. Nanoethics 1 (1), 31–46.
Nordmann, A., 2014. Responsible innovation, the art and craft of anticipation. Journal of Responsible Innovation 1 (1), 87–98.
Owen, R., Macnaghten, P., Stilgoe, J., 2012. Responsible research and innovation: from science in society to science for society, with society. Sci. Publ. Pol. 39 (6), 751–760.
Seabrook, J., 2020. "The Age of Robot Farmers" 2020, *the New Yorker*. Extracted July 22, 2020 from. https://www.newyorker.com/magazine/2019/04/15/the-age-of-robot-farmers.
Schneider, C., Lösch, A., 2019. Visions in assemblages: future-making and governance in FabLabs. Futures 109 (September 2018), 203–212.
Stahl, B., Obach, M., Yaghmaei, E., Ikonen, V., Chatfield, K., Brem, A., 2017. The Responsible Research and Innovation (RRI) maturity model: linking theory and practice. Sustainability 9 (6), 1036.
Stilgoe, J., Owen, R., Macnaghten, P., 2013. Developing a framework for responsible innovation. Res. Pol. 42 (9), 1568–1580.
Van Der Ploeg, J.D., 2010. The food crisis, industrialized farming and the imperial regime. J. Agrar. Change 10 (1), 98–106.
Vik, J., Stræte, E.P., Hansen, B.G., Nærland, T., 2019. The political robot–The structural consequences of automated milking systems (AMS) in Norway. NJAS - Wageningen J. Life Sci. 90, 100305.
Von Schomberg, R., 2011. *Towards responsible Research and Innovation in the Information and communication Technologies and security technologies fields*. Available at: SSRN: https://ssrn.com/abstract=2436399.
Von Schomberg, R., 2013. A Vision of Responsible Research and Innovation. *Responsible Innovation: Managing The Responsible Emergence of Science and Innovation in Society*, pp. 51–74.
Winder, G.M., Le Heron, R., 2017. Assembling a Blue Economy moment? Geographic engagement with globalizing biological-economic relations in multi-use marine environments. Dialogues in Human Geography 7 (1), 3–26.
Worster, D., 2004. Dust Bowl: the Southern Plains in the 1930s. Oxford University Press.