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Interacting imaginaries in the making of an alternative future in agriculture

The case of strip cultivation in the Netherlands

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A la familia que me vio crecer,
a la familia que escogí,
y a todos aquellos que me han aportado en el camino.

To the family that raised me,
to the family I chose,
and to all who have enriched me with their visions.

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List of Acronyms

BvdT	Boerderij van de Toekomst
CAP	Common Agricultural Policy
FAO	Food and Agriculture Organization
ISS	Institute of Social Studies
NPPL	National Experimental Garden for Precision Agriculture
PR	Pixelfarming Robotics
SC	Strip Cultivation
SF	Smart Farming
SH	Soil Heroes

Abstract

This research paper explores the process of materialization of alternative futures in agriculture, in particular of strip cultivation in The Netherlands. It showcases how this process involves not only the interaction of farmers with a new equipment configuration, but also an expanded understanding of the role that biodiversity plays in farming. Given that strip cultivation has not been sufficiently studied, the adoption of this technique has led to the collaboration between farmers, researchers, and technology developers to fill this knowledge gap. This paper presents the experiences of some of these actors involved making use of the concept of land imaginaries, tinkering, and domestication. Thus, analysing the underlying elements that motivate the adoption of this technique, the interaction of knowledges in the continuous process of adaptation of equipment and practices and its expressions in the changing landscape.

Relevance to Development Studies

As digital technologies and strip cultivation are introduced in agriculture as an alternative to the environmental and societal effects of conventional practices, it is important to go beyond analyzing what these techniques have to offer and the material effects from their use. By studying the agency of its users to frame this relationship and the different imaginaries that sustain it, multiple futures unfold. This research aims to explore how different values and knowledges interact with productivist techniques to open new possibilities to a future that is conscious of the more than human world. This research goes beyond the positive narrative promulgated by the hegemonic institutional framework. It is built upon the plural ways of thinking of those who adopt, adapt, and develop these technologies. Thus, it explores the extent to which the skewed power relation between farmers and agricultural technology providers has a role in the promotion of a more sustainable way of farming, strip cultivation.

Keywords

Strip cultivation, land imaginaries, socio-technical imaginaries, precision agriculture, smart farming, tinkering, domestication triangle, NPPL, Soil Heroes, Pixelfarming Robotics, Trabotyx.

Chapter 1
Introduction

1.1 What is this research paper about?[1]

In the different encounters I have had with agriculture, I had the opportunity to experience the wide range of values that sustain the relation of agricultural producers to land, and consequently the different meanings that land can have. One of the ways that these values and understandings materialize is in the choice of the technologies used to grow food. These technologies shape the soil as the crops create patterns on the landscape, they shape the bodies and the relations of those who use them, which at the same time adapt technologies to the purpose they aim to achieve (Finstad, Aune and Egseth, 2021). These interactions are expressed in the plural ways of farming, which contain a great diversity of possibilities. I experienced this diversity along South America, where I got to know different agricultural worlds, shaped by different land imaginaries (Sippel and Visser, 2021). By relating to the land in different farms, I had the opportunity to see how the way the agricultural producer understood land and the technologies used, manifested in the diversity of the landscapes and therefore of the produce (Figure 1). Furthermore, these technologies end up shaping the bodies that use them. The substantial physical effort that some of these technologies demand becomes evident in the thick and arthritic fingers of elders and their humped backs (Figure 2). These bodies not only contrast with those that use mechanical equipment as these implements reduce the drudgery of the manual labour, but also raises questions related to the trade-offs behind these choices. For example, how these technologies would allow

Figure 1 – Diversity of landscapes shaped by plural land imaginaries.
Machu Picchu, Peru (upper left). Finca El Silencio, Colombia (upper right).
Aldea Kuruksetra, Ecuador (bottom left). Finca Urkuwayku, Ecuador (bottom right) (Bicionarios, n.d.).

[1] This section is inspired on an essay for the course 4354 – Transitions for Social Justice Lab.

Figure 2- Bodies shaped by the technologies used to grow food (Bicionarios, n.d.)

farmers to have more time for other activities at the expense of losing some autonomy by depending on others to fix and maintain more complex equipment.

With the aim of increasing productivity by increasing yields and improving energy efficiencies, agricultural technologies have transformed landscapes and triggered different imaginaries that have shaped agriculture as we know it. Since the Green Revolution in the decade of 1960s, the use of chemical inputs and greater mechanization has led to the cultivation of increasingly larger areas of monocultures. Thus, food became commodified, and the understanding of land was equally transformed. The conception of the economic, social and cultural capital of conventional agricultural producers has shifted towards a productivist understanding of agriculture were yields, and orderly fields have become symbols of 'good farming' (Sutherland and Darnhofer, 2012). Moreover, the increasing demand of energy that accompanied this transition and the consequent acidification of the soil are having a significant impact on biodiversity and are contributing significantly to the current climate crisis (FAO, 2012). To mitigate these impacts, a new revolution is unfolding around the use of digital technologies for food production, Smart Farming (SF). Some of these technologies are soil sensors, applications for market price information, applications for localized weather forecasts, and decision support systems. Even though SF is just starting to consolidate as a new way to produce food, it already claims to be a triple win solution that can be used to increase food security, reduce rural poverty levels, and mitigate the environmental impact of food production (Bacco et al., 2019: 1).

This new agricultural revolution deepens the pre-existent reliance of farmers on knowledge that comes from domains other than agricultural. This means that the power relations between the agricultural producers and the technology providers are skewed even further. One of the different ways by which this takes place is through the development of proprietary technologies that commodify knowledge through patents and licenses. Thus, agricultural knowledge shifts away from the field and from the farmers, to laboratories, industries and computer scientists that counterfeit *the vernacular* by commodifying it and presenting it as something entirely new (Illich, 1981). However, Ingram and Maye (2020) point out how digital technologies transform the dynamics of knowledge creation, as farmers and other actors develop knowledge-exchange mechanisms, like informal networks, to enhance learning and innovation. They show how there are already mechanisms like cooperatives and online communities to "create and share knowhow, technologies and experiences, and big data understanding (p. 4). This is an example of how the imagined futures that emerge from a wider adoption of digital technologies animate action and shape thought (Carolan, 2020).

From the interaction of these different imaginaries, various technologies are being developed. While they might not necessarily close the gap between the technical knowledge of the developers and of the farmers, these technologies offer solutions that range from the continuation of conventional practices through automated monocultural cultivation, to opensource multicultivation technologies. However, regardless of their position in this spectrum, these technologies face numerous challenges that lead to their uneven adoption. Some of them are the difficulty for farmers of evaluating their advantages, the time to recover the investment, and the lack of compatibility of these technologies with the machinery they currently use. Therefore, to increase their adoption, it is important to address the high costs of these technologies, concerns on data ownership and use, the low digital skills of numerous farmers, and the top-down approach of current solutions (Bacco et al., 2019). To address the last two, researchers and farmers work together in the National Experimental Garden for Precision Agriculture (NPPL) in the Netherlands, on the adoption of different techniques that include precision spraying for fruit cultivation, variable fertilization, robot applications in open and strip crops. The latter differs from the rest as it takes distance from the practices of conventional agriculture. Strip cultivation consists of having several crops per plot in strips of widths that vary from 3 to up to 30 meters (Figure 3). This increases the biodiversity in the growing process and protects the health of the soil. Additionally, this technique allows for less pest pressure coming from neighbouring crops, a chance of higher crop yields and new outlets/shorter chains given to gained access to organic markets.

The confluence of the digital with the implementation of a new way of farming for entrepreneurial agriculture brings together an imaginary of land (Sippel and Visser, 2020) that contemplates environmental factors, but also a sociotechnical imaginary (Jasanoff, 2015) proper of modern agriculture. It is precisely in this process of adoption, where two seemingly conflictive imaginaries are negotiated to create a new understanding of *good farming*, that I aim to focus my research.

Figure 3 – Examples of strip cultivation and its weeding through digital technologies (left: NPPL (n.d), right: IOF 2020(2021)

The encounter of these imaginaries builds a bridge between two conflicting visions that exist in the Netherlands regarding the role of agriculture in the current energetic and climatic crises. Van der Ploeg (2020) presents how since the 1950s Dutch peasant agriculture has been restructured into an entrepreneurial agriculture on which some peasant-like ways still persist. However, the main style of farming is characterized by being capital intensive, dependent on input-use, specialized and engaged in ongoing expansion. Now, farmers are divided between those who acknowledge that the current system of food production has affected the autonomy of the farmers and is not feasible in the longer run, and those who support the export orientation of agriculture associated with an increasingly larger scale and ruthless competition. Nonetheless, it is important not to fall into the trap of reducing "the persistence of entrepreneurial farming to the assumed unwillingness of those farmers to change while not paying much attention to the structural path-dependency and other mechanisms that lock these farmers into the dominant socio-technical regime" (van der Ploeg, 2020: 602). Hence, the NPPL project with strip crops attempts to reconcile the need to reduce the environmental impact of farming while building upon the existent technical know-how of the industry. Although it will not be the aim of my research to explore the extent to which this might be a viable solution, I want to explore how different values and knowledges of farmers interact with productivist techniques to pave the way to new possibilities.

Even though there are authors that have not found substantive evidence to support the claim of digital technologies to effectively be a triple-win strategy (Gatti and Visser, 2021), this research explores the role that the tinkering of dominant technologies has in the development of an alternative that is more conscious of the human and non-human world. By going beyond a focus of producing, and instead focus on nurturing. Thus, contributing to the understanding of transition discourses that highlight the "need to reconnect with each other and with the nonhuman world [through] the relocalization of food, energy, and the economy […] advocating for […] strong communal bases, even if not bound to the local" (Escobar, 2015: 454). Moreover, as this project challenges the top-down verticality of knowledge production by promoting the interaction of farmers, researchers and technology developers, it opens the thought, practice and being to multiple possibilities. In doing so, it fosters dialogical spaces that turn "towards the other and co-construct[s] the conditions for voice, speaking and listening" (Motta 2016: 41). It is in such spaces in which the different land imaginaries interact, not only between farmers, researchers, and technology developers, but also among them as their imaginaries might differ as well.

Thus, as a foreigner to the Dutch culture and to the technical field of agriculture, my aim is to expand my understanding of the new worlds I will encounter, and how they shape the possible transition that arises. In the end, "without knowing the others' 'world', one does not know the other, and without knowing the other one is really alone in the other's presence because the other is only dimly present to one" (Lugones, 1987: 18). In the terms used by Illich (1981), smart farming technologies are in the crossroads to either further conceal the vernacular, or to give the latter a new vitality that gives a new opportunity to multiple vernacular forms. This research is aimed to shed some light on the encounter of different narratives of production and care and how they negotiate their values while learning and creating knowledge. To do this, the Chapter 2 will present the theoretical framework of the research, Chapter 3 will contain the results from the interaction with the participants, Chapter 4 analyses the latter through the lens of their land imaginaries, and Chapter 5 concludes.

1.2 Research Objectives

Conventional agricultural practices in the Netherlands have led to increasing levels of compaction on the soil (Wouda, 2019), a decrease in biodiversity (MENA Report, 2019), and therefore a greater dependence on external inputs for ensuring the profitability of farms. These factors added to the competitive pressures derived from a constant push for increasing productivity (Levins and Cochrane 1996) have led to a search of alternative ways of growing food. Through regulation, public institutions are promoting digital technologies that are meant to contribute to this goal (EC, 2021), while disincentivizing the use of agrochemicals to achieve a residue free process of production (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2020). SC is one of the alternatives that is currently being researched and practiced on which the two objectives being pursued through regulation coincide. Hence, the objectives of the current research are:

- To explore the process of materialization of alternative futures in agriculture, in particular strip cultivation in The Netherlands.
- To explore the land imaginaries of farmers, developers, and researchers involved in the tinkering of digital technologies for strip cultivation.
- To critically analyse the interaction of farmers' and technology developers' knowledges in the process of adoption of strip cultivation techniques.

1.3 Research questions

Main Question

- How do technology developers' and farmers' imaginaries interact in the process of transitioning towards a more biodiverse agriculture by adopting strip cultivation techniques?

Sub-questions

- Which factors led to the decision of shifting to strip cultivation and adopting digital technologies?
- How have the farmers' land imaginaries evolved to the point at which they are willing to adopt strip cultivation techniques and to include digital technologies?
- Which trade-offs do farmers experience from the adoption of digital technologies for strip cultivation?
- To what extent does farmers' knowledge contribute to making digital technologies user-centric and context appropriate?

1.4 Methodology, methods, and positionality

To explore the answers to the research questions I used semi-structured interviews with the representatives of the NPPL project for SC, of Pixelfarming Robotics (PR) and Trabotyx as technology developers, and of Soil Heroes Foundation as user of digital technologies for strip crops and regenerative agriculture. The participants were reached out via email and in some cases I had the opportunity to meet them first in NPPL demonstration days in Andijk, Reusel or Lelystad. The fact of being a Colombian student interested in researching digital technologies implemented in Dutch agriculture called their attention and allowed me to establish rapport and to present myself as a person who is not completely familiar with the Dutch agricultural context. This led the interviewees to express their ideas in greater detail and with a broader context, which gave me a better understanding of their experiences. Nonetheless, the fact that I do not speak Dutch affected the easiness of the conversation in some cases. This was especially challenging when interacting with farmers as some of them did not feel comfortable speaking in English. This research is built upon three interviews with researchers of the NPPL project, two interviews with the CEO of PR, two interviews with the co-founders of Trabotyx, three interviews with the director and modelling expert of Soil Heroes, and the assistance to three demonstrations of digital technologies organized as part of the NPPL project. As it can be noted, farmers are absent from this list as I was not able to talk to them. Some of the reasons behind this include the uneasiness to speak in English, the lack of time as they were busy with the harvesting season, the absence of a compensation for their time, and considering that they were not experienced enough on the subject to add value to this study. For this reason, I made use of secondary data to explore their perception and experiences when adopting SC. This was possible as this technique has been gaining the attention of farmers and journalists given that it has been (re)introduced only recently to the Dutch agricultural landscape. Twenty-two news articles from 2018 to 2021 were reviewed with this aim.

The interviews were performed with what Kvale & Brinkmann (2009) define as a traveller approach. This approach recognizes knowledge as the outcome of a process of construction that results from the interaction with the interviewee. The researcher (traveller) is an active participant in the process and gets involved even to the point of being changed along the pursuit of new knowledges. For the traveller, the analysis of the information gathered takes place while it is being discussed and uncovered. The interpretation and recollection are enmeshed and therefore is dynamic and dependent on the agency of the interviewer and the interviewee. This active involvement and openness to change manifested in the making of the interviews as the discussion about the potential of SC gained relevance over the adoption process of smart farming solutions. Nonetheless, this process kept on being an important element of the conversation.

The transcripts of the interviews were processed and codified by making use of the software AtlasTi to further explore relationships between concepts, attitudes, and others. Open and axial coding were used to find relationships between the responses of the participants. This process is iterative as the analysis is revisited with every interview that takes place. The results will be shared through storytelling to highlight the importance of the context and its participants (Hill, 2002), while making use of photography to further contextualize the discussion.

1.5 Ethics and the influence of the Covid-19 pandemic

The fact that the Covid-19 pandemic was taking place during the time that the fieldwork for the current research was performed demanded to take additional considerations for the safety of all the participants. First, the ISS Institute Board requested to every student that was planning on having in-person interactions for the elaboration of their research paper (RP) to design a safety protocol according to the characteristics of each project (Appendix 1). Second, I decided to wait until completing my vaccination scheme to start visiting the farmers and developers that were going to be part of the project. Thus, I would reduce my own risk of getting infected and infecting the people I was going to interact with. Third, the sanitary restrictions and recommendations from the government were followed throughout the process. By following these measures, I was able to attend three events of the NPPL project, to visit farmers, and demonstrations of precision agriculture. Some interviews were also made online to mitigate the risk of a possible infections.

The request for the consent of the participants to take part of this research was done after discussing openly the objectives pursued and the audience to which it is directed. After this, a form was sent to every interviewee which gave further information of the research objectives and the purpose of the data collected. The form also addressed privacy and anonymity concerns for the realization of the transcripts and the publication of the results.

Chapter 2
Conceptual and theoretical framework

In this chapter I develop the conceptual and theoretical elements that will inform this research. The three axes around which this revolves are (i) strip cultivation as a farming technique, (ii) an analysis of the interaction of farmers with digital technologies by addressing its emergence as a continuation of modern agriculture, the underlying power unbalances, and the way that farmers adapt them to their needs, and (iii) the relevance of land imaginaries in the process of shaping multiple futures. Then, I introduce the organizations and the representatives with whom I interacted to address the research question mentioned in the previous section.

2.1 Strip Cultivation

Strip cultivation (SC), the simultaneous farming of multiple crop species in a single field (Vandermeer in Cong et al., 2015), is a field management technique that dates to the 13th century and stopped being employed in the late 1940s, when food shortages led to agricultural intensification (Morris, 2018). As large-scale agriculture became the norm, many insects lost their food and shelter after every harvest which affects the process of pollination and plague control (MENA Report, 2019). Even though SC was introduced as a way for villagers to share land, several experiments have proven its beneficial effects for agriculture. Strip cultivation, or strip intercropping (Cruse et al*.,* 1992), consists of the sowing of different crops in strips from 3.5 m up to 40 m wide in the search of synergistic relations between them. This practice has proven beneficial for increasing biodiversity (Morris, 2018; MENA Report, 2019) and consequently for enhancing soil carbon and nitrogen (Cong et al., 2015), reducing the effects of diseases and plagues (Gao et al., 2021), and even weed management (Liebman and Dyck, 1993). This gains special importance in the Netherlands as agricultural areas are home to half of the biodiversity in Dutch soil, and it has been declining drastically (MENA Report, 2019).

While some report that SC "is not for now an economically viable form of farming" (Morris, 2018), others find it a potential strategy for agroecological intensification (Cruse et al*.,* 1992) that "usually give higher yields per unit area than sole crops as measured by the land equivalent ratio" (Cong et al., 2015: 1715). For some Dutch farmers the decision to adopt this technique depends on finding an additional advantage when selling their produce, thus offsetting the inefficiencies that SC implies (Tholhuijsen, 2021). This will depend as well on whether the produce is grown in a conventional or in an organic way, as the benefits for conventional farmers might not be substantial given that they can keep on using chemical inputs for crop protection and will sell at world market prices. However, there is increasing pressure on the use of these products as the government of the Netherlands has already established a goal of achieving a more sustainable production with resilient plants and cultivation systems by 2030. This implies virtually no emissions to the environment and virtually no residues by preventing the use of plant protection products (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2020). Hence, the importance of increasing the biodiversity above and below the soil to promote natural pest control and increase the level of macro and micronutrients within it. Arguably, the company with the most area devoted to SC in the Netherlands is ERF, the largest organic arable farm in the country with 1,450 ha, from which close to 100 are planted in strips. When asked about the efficiency of SC compared to conventional farming, the director Jaco Burgers responded:

> "Strip cultivation is a bit more labor-intensive than standard arable farming, but not much. The more stable yield outweighs this. The benefits outweigh the higher costs" (van Reenen, 2020)

After which he complemented:

> "I dare not call it [the egg of Columbus] yet, because we have only been working for three years" (van Reenen, 2020)

Although SC is considered a method for small scale production, Burgers considers that it is the large scale of their fields what maintains this technique with similar processing times to conventional farms. Every strip of their field is 7 ha while being just 6 m wide (Tholhuijsen, 2020). However, these positive impressions are not shared by the experimental farm Rusthoeve in Colijnsplaat (ZL) on their second year of trials with SC and conventional practices. For them, the varying weather conditions and variation in the clay content of the soil have not allowed them to perceive any benefit from this technique. They decided to change the orientation of the strips aiming for less variation of the soil conditions within the lanes. Still, they were unable to achieve the higher yields that the research by WUR has indicated SC generates (de Vriend, 2021). The experience of the Rusthoeve farm has led its advisors to conclude that more research is still needed, which could take up to ten years.

The contrast between the good results of some entrepreneurs and the attention it calls from other farmers, leads to a lack of trust due to the short time of experience with it and the scarce scientific evidence and technical support around it. To mitigate this, farmers, cooperatives, and research institutes have ventured into the experimentation of alternative farming in general, and SC in particular. One of these projects is the NPPL project led by Wageningen University and Research to further study its potential benefits, but also to increase the practicality of its implementation by developing digital solutions for its mechanization. Another one is the Soil Heroes (SH) Foundation, which has been using regenerative practices for over a decade and adopted SC in 2021 as an additional step towards a more biodiverse agriculture. Both will be further introduced in a following chapter.

2.2. Farmers' interaction with digital technologies

The World Bank and other multilateral organizations emphasize the need to increase the efficiency and volume of food production to meet the demands of a population that is expected to reach 10 billion by 2050. Such emphasis on increasing productivity serves as an expansion mechanism for modern agriculture, which is characterized by an increased mechanization, use of agrochemicals, and water control systems to produce a reduced variety of monocultures. A logic embodied in agribusiness that focuses on the reduction of costs, the increase of yields, and the consolidation of actors along the supply chain. This quest not only has led to environmental degradation (FAO, 2012), but has impacted the agrarian society through an increasing concentration of control over land derived from a capital-intensive system of production that relies on an industry that has transnational control over input supply and market chains (Woodhouse, 2010: 449).

Organizations like the FAO, the World Bank, and the OECD portray digital technologies as an alternative to overcome these impacts. Some of their advantages include better monitoring and control of agricultural production processes. Thus, increasing productivity while reducing the environmental impact by using inputs more efficiently (Sundmaker et al., 2016: 131). However, these technologies are accompanied by a concentration of power from agriculture technology providers as the degree of sophistication of the techniques used in food production increases. This takes place as knowledge is progressively being transferred away from the farmer, who becomes ever more dependent on the providers to interpret the data gathered, modify it for different uses, and even to repair the equipment. Thus, agricultural producers are being pushed into a technological treadmill that forces them to update their inputs and techniques constantly to be able to compete (Levins and Cochrane 1996). The strong reliance on technology to find a solution to the expected increase of the population combines techno-optimism with a neo-Malthusian, market-oriented approach (Klerkx and Rose, 2020: 2). This approach comes close to technological determinism, which sees "technology as independent from societal influence and its progress as fixed" (Giotitsas, 2019: 72).

Still, there are different paradigms that are informing the trajectories that digital technologies are paving in agriculture and that coincide in the different Agricultural Innovation Systems (AIS). The interaction in these AIS of agricultural research and education organizations, advisory organizations, private sector actors in the value chain, agricultural cooperatives, public organizations, professional organizations, and farmers, creates a complex web of socio-technical configurations that pursue different aims and are shaped by different rules (Dumont in Schnebelin et al., Forthcoming). For instance, increasingly organic farmers are engaging with digital solutions for the management of their farm systems as an expression of the hybridization between organic and conventional organizations. This hybridization is the result of conventional organizations engaging with organic farming, and from organic farming organizations that are incorporating innovations to scale-up (Schnebelin et al., Forthcoming). Nonetheless, Schnebelin et al. (Forthcoming) identified that there are also divergences regarding their expectations from engaging with these solutions. While organic farmers "underline the importance of farmers' training and of the design specific technologies to support their own vision of digitalisation [,] conventional actors collaborate with digital actors with the aim of rendering farmers' activities simpler and more efficient" (p. 10). This difference, as well as others identified by the authors, denote the heterogeneity of definitions and approached towards digital technologies.

Such complex dynamics of transformation of agricultural practices indicate that digital technologies are but one component of the process, others being changes in advisory services, new relations with consumers, new policies supporting open innovation, and farm structure (Schnebelin et al., Forthcoming). As these actors interact around the fields of agricultural producers, the latter experience their own dynamic of transformation. At the farm level, in the process of adapting digital technologies for SC, farmers participate in a three-way process of domestication (Finstad and Egseth, 2021). First, the farmers need to learn how to incorporate the new techniques and equipment into their daily practices. This is particularly important given that these technologies are not rationalization machines that replace human workers, but rather produce new kinds of labour for their users (Holloway and Bear in Finstad and Egseth, 2021). As it will be discussed further in the following sections, SC demands additional planning to define the layout of the different crops on the field. Some of the considerations include the mutually beneficial relation of neighbouring crops, but also the way machinery will perform the corresponding tasks from soil preparation to harvest. Second, the landscape is transformed as the uniformity of the plots is substituted by a synergistic selection of crops that coexist within the same plot while increasing nitrogen fixation and carbon sequestration in the soil (Cong et al. 2015). Moreover, the projected increase in biodiversity above and below the soil is expected to result in a natural pest control. This takes place, for instance, when insects that feed on parasites find shelter in neighbouring lanes (Gao et al. 2021). Thirdly, the machines also learn to adapt to the differentiated requirements for each crop within the field and doing so in strips of widths that can range from 3 to 40 meters wide. This does not mean that the equipment learns by itself. Instead, over time, it learns from its interaction with the different crops, the farmers, and the technology advisors who master how to handle unexpected outcomes after the machinery has been installed.

The 'liveliness' of this process of domestication gains special importance when considering the inherent im-precision of some of these technologies. Farmers start from a basis of trust regarding the reliability of the equipment they use, it is the starting point from which the process of domestication takes place. However, while claiming high levels of accuracy thanks to the objectivity of data-driven decision making, some of the solutions in precision agriculture present several smaller inaccuracies that end up creating a 'precision trap' (Visser, Sippel and Thiemann, 2021). For Visser et al. (2021), this trap refers to the opacity of algorithms that end up crowding out more qualitative, situational, and experimental forms of knowledge. Such opacity inhibits users to see the shortcomings of the algorithms and exposes them to an *implementation gap* between the expected performance of technologies in trial fields and the weaker results under the diverse conditions of ordinary farms (Sumberg in Visser, Sippel and Thiemann, 2021). This adds up to a precision divide that exists between commodity crop farms for which digital technologies are primarily developed and farms with more demanding practices (Visser, Sippel and Thiemann, 2021). This includes employing techniques like SC that make use of rotation schemes, which pose greater challenges for these technologies and for which solutions are still to be developed to the same extent.

To make up for the lack of specific digital solutions for SC, farmers and technology advisors negotiate, work with, and work around their constraints using their capabilities on tinkering the available technologies. Higgins et al. (2007) define tinkering as a practice of careful experimentation, adaptation, and embodied learning to incorporate non-farm cares, such as environmental management and digital technologies, in the case of this research. The adaptation of digital solutions for SC exemplifies how, through tinkering, alternative and dominant practices exist side-by-side to constitute an alternative form of ordering (p. 201). For instance, Heijting et al. (2011) point out how farmers' practical knowledge of within-field variation of soil, yield, pests, and weed infestation should be regarded as an important information source for the development and functioning of precision agriculture systems. This process serves to highlight the importance of farmers' embodied skills and practical judgement in the process of "adapt[ing] their tools to a specific situation while adapting the situation to the tools, on and on, endlessly tinkering" (Mol et al. in Higgins et al., 2007: 199). In the Dutch context, the constant increase of the scale of the farms, the pressure to provide affordable food, the change in the environmental conditions and the increasing regulation to mitigate the impact of agriculture, are just some of the factors that influence farmers and developers to keep the tinkering process going.

2.3 Interacting land imaginaries in the adoption of digital technologies

The development of precision technologies for agricultural use corresponds to a technological system that is already established and from which it is costly to deviate. This dynamic is known as technological lock-in and leads potential adopters to make the decision of adoption based on the short-term costs even if switching to a different system may be more beneficial over the long term (Clapp and Ruder, 2020: 59). However, this doesn't mean that every precision farming technology is oriented to the continuation of an agricultural model based on monocultures and on a continued dependence on chemical inputs. There are also start-ups that are still independent from major corporations and that want to contribute to an agricultural system transformation that is more sustainable and that encourages greater biodiversity. It is this category that projects like PR, SH and the NPPL project of adaptation of digital solutions fall in. Hence, the relevance of exploring further the social effects of this technological change to better understand and interpret the emergence of alternative futures. The insights from this research might contribute to informing the development of potential regulatory frameworks that govern these technologies (Clapp and Ruder, 2020).

It is equally important to nuance the motivations with which farmers are approaching digital technologies as they not necessarily respond exclusively to an economic rationality. Beyond economic capital, farmers also respond to alternative sources of wealth as their social capital (networks of social connections and mutual obligations) and cultural capital (prestige, status in the community). It is the interaction of such material and symbolic factors that creates a set of principles based on values and standards that end up defining the image of 'good farming' (Sutherland and Darnhofer, 2012). While some of the most common symbols include high yields, tidy fields and good quality livestock, these symbols evolve gradually in response to changing technology. They are often geographically bounded and specific to regions and the commodities produced in them. Therefore, the adherence to these standards may be associated with farmers' resistance to change towards different models of production (Burton in Sutherland and Darnhofer, 2012: 232). Such resistance can hinder even the adoption of more sustainable farming practices when these are not aligned with the local image of 'good farming'. When researching the resistance to the implementation of agri-environmental schemes, Burton, Kuczera and Schwarz (2008) identified that allowing farmers to innovate in the process and limiting the use of predetermined parameters allows for an increase of cultural capital in terms of prestige, and for the voluntary re-evaluation of preconceived standards. From this, new questions emerge about the interaction of farmers with technical partners in the tinkering process, the focus of this research. To what extent is the adoption of digital technologies a source of prestige among these farmers' communities? How does SC stand in accordance with the current symbols of 'good farming'? Will the interaction between farmers and technical partners initiate a reconsideration/re-evaluation of the standards of 'good farming'? While these questions might not be fully addressed, they inform the conversation held with the participants and provide input for future research.

Nonetheless, as stated in the previous section, the process of adoption of these digital solutions goes beyond the subjects themselves and includes the interaction of them with the soil, mediated by the digital equipment. Hence, the understanding of land and its relevance in the process of production might evolve from the adoption of a new growing technique. To explore if and how this takes place, the notion of land imaginary is particularly helpful as it is grounded in the overlapping of environmental, sociotechnical and spatial imaginaries (Sippel and Visser, 2021). Such land imaginaries "encompass the various societal understandings of what land is (…), its different uses and values (…), and ideas of what it can, or should, do in society" (Li in Sippel and Visser, 2021: 274). These can either be implicit components that inform practical engagements with land but can also become an explicit and conscious driving force of land transformations. For Jasanoff (2015) imaginaries are not to be reduced to mere projections or predictions. On the contrary, she highlights how they are a political narration of a society's particular sightedness and blindness and the trade-offs that inevitably accompany attempts to build a *shared normative order*. The author defines sociotechnical imaginaries as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff, 2015: 322). Thus, imaginaries go beyond linear causality and acknowledge how imagination, objects and social norms become fused in practice.

Projects like NPPL respond to the objectives of policies to strengthen the digital potential of agriculture (EC, 2021), developing new solutions that materialize particular imaginaries. This takes place through objects and habits of social interaction that lead to their embedding into new local constellations of production and practice (Jasanoff, 2015).

However, this does not mean that these imaginaries are entirely new, they are modifications of existing imaginaries that can become "an explicit and conscious driving force of land transformations if they express actively envisioned land futures (yet) to be realized" (Sippel and Visser, 2021: 274). Hence, the exploration of these imaginaries implies the understanding of their historical place-based trajectories and how they manifest in the agricultural frontiers, how the imaginary and the material interact to produce new land imaginaries, and how they are connected to the emotional, affective, performative, and embodied aspects of land use and its possible futures (Sippel and Visser, 2021).

In the projects presented in this research, the interaction of farmers' and researchers' imaginaries contribute to the consolidation of a new set of agricultural practices. It is not only the material conditions of land, crops, and the equipment that they are working with which determe the outcomes from this interaction, but the relational character of their imaginaries and knowledges. While farming knowledge might be distinctive from 'scientific' knowledge, both are related given that the former brings the farmers' expertise in their own fields, while the latter is aimed to extend its reach through the development of solutions through science (Higgins et al. 2017). Thus, the adaptation of existent technologies is a co-production of social and material products that influence "how farmers come to 'know' and implement technology, and the subtle yet powerful ways in which they work with and work around technology to make it adoptable on-farm" (Higgins et al. 2017: 201). However, it is argued as well that reliance on information-intensive technologies has the potential to substantially change the way knowledge is processed, communicated, accessed, and utilized. The increased complexity of constructing, maintaining, analyzing and sharing farm data, limits the potential of these solutions to provide high information value to producers, while potentially augmenting their reliance on technical experts at the expense of farmers' tacit knowledge (Ingram and Maye, 2020). However, farmers have shown the capacity to learn how the "experiential processing can combine with analytical processing, where information is obtained through statistical description" (Ingram and Maye, 2020: 3). Interpersonal networks are an important source for farmers "to create and share knowhow, technologies and experiences, and big data understanding" (Ingram and Maye, 2020: 4).

This is not to say that the role of farmers should be limited to learning how to interact with digital solutions. On the contrary, there is great potential in tinkering as a way to build the capabilities of smart farming tools as tinkering sheds light on where and how technologies and farm data could best help producers (Eastwood et al. 2019, Ingram and Maye, 2020). Eastwood et al. (2019) point out the important role that technology advisors play in this process due to their hybrid knowledge, meaning the ability to make links between digital data and how to integrate it into farm management decision making. By interacting with farmers' knowledge, such a process of tinkering can be a focal point of power struggles between knowledge forms especially as relational knowledge building moves from technology-centered to actor-centered (Bruckmeier and Tovey, 2008). Nonetheless, while inequalities in power, knowledge, and access to resources need to be considered, it is important to analyze how the constructivism in knowledge processes "can help to reconnect social and natural systems" (Bruckmeier and Tovey, 2008: 325). As the relational character of knowledge implies a negotiation between farmers and the technology advisors for a new joint purpose, this research will explore how and to what extent their land imaginaries inform such interactions as well.

Chapter 3
Strip cultivation and technology development on the field

This chapter introduces the projects that were reviewed to address the research question of this paper. It is important to clarify that, although the aim is to analyze how technology developers' and farmers' imaginaries interact in the process of transitioning towards a more biodiverse agriculture by adopting SC, these actors are not necessarily representative of farmers' knowledge and technology developers' knowledge. These actors were addressed due to their experience with alternative ways to approach agriculture, and their interest in contributing to a transition to a more sustainable way of growing food. Firstly, I will introduce the elements that characterize them and their experiences transitioning towards a more biodiverse agriculture. The following chapter will delve into some of the imaginaries behind their work.

3.1 The Soil Heroes Foundation and their venture in regenerative agriculture

When approaching the Klompe Farm, strips of different tones appear by the side of the road. It is hard to miss them as you approach the entrance of the farm (Figure 4). Located in Mijnsheerenland in the Province of South Holland, the Klompe farm is one of the largest in Europe that is involved with regenerative practices. From its 360 hectares, 170 are being farmed regeneratively and 20 of those have been destined for trials with SC. In the latter plot, Mellany and Jeroen Klompe have decided to plant six different crops in lanes that are 6 meters wide. This includes soybeans, two types of wheat, oats, rice, and biodiversity lanes that serve as shelter and as a source of food for insects and birds. Upon arrival, tractors that were adapted according to the width of the strips (see Figure 7 for reference) and variable spraying equipment were parked outside the storage buildings where machinery, inputs and harvest was kept (Figure 5). In the office on the second floor of the first storage building Mellany Klompe and Leandro Barberi, an expert on the biology and chemistry of soil who is involved in the project, generously shared their experience along the seven years transition from conventional practices to RA.

Along the history of this third-generation family farm and during the first decade of Jeroen's leadership, conventional practices led to soil depletion and loss of fertility. To remain competitive, they decided to plant specialty crops and to look for short supply chain models. They stopped cultivating onions and sugar beets, and introduced sorghum, quinoa, and soy for human consumption. Also, instead of planting only one variety of potatoes, they plant 13 special varieties that have different maturity times. This to reduce the stress put on the soil during harvest due to the passing of the harvesting equipment. Nonetheless, the decrease in water retention of the soil and the pollution of water from slurry motivated a greater transformation of their farming practices. Thus, Mellany decided to quit her job at the Dutch Water Boards and join Jeroen full time in the leadership of the farm operation and the implementation of regenerative practices. As explained by Mellany during our meeting, RA focuses on increasing the biodiversity above and below the soil. Above, it aims to promote natural pest control by ensuring the necessary area for insects and birds. Below, it looks for a porous structure where air, roots, fungi, insects, and water have the opportunity to interact. As a result, crops are more resilient to pests and draughts while leaving behind the dependence on chemical inputs to achieve competitive yields. However, this does not mean that the transition was swift and smooth. Among the greatest challenges in this process are the increasing weed pressure in the first years, and the *soil's addiction* to chemical fertilizers. The latter consists in the reduced availability of micronutrients in the soil, which play a key role in the development of the crops. Still, after overcoming these challenges and convinced that RA is a viable alternative that should be adopted in a wider basis, the Klompe family founded SH. This foundation has the goal of sharing knowledge based on science that informs the decision of interested farmers to adopt RA.

Transitioning process

SC is the technique implemented in the Klompe farm that encompasses the greatest array of regenerative practices, and it has not come cheap. Some of the regenerative practices implemented prior to SC are the use of shallow or low tillage in order to avoid affecting the structure of the soil, the use of bio-fertilizers and organic inputs for pest control, the use of cover crops, and planting flowers and grass-herbs for the habitat of insects and birds. Since 2021, with SC they have increased the benefits of crop diversity and are aiming for a greater resilience to pests, diseases, and extreme weather conditions. This is only the start of a journey to explore the best ways to manage crop selection, crop rotation, plot design, among others. For Mellany this will be a process that will take at least two or three more years.

The application of SC has demanded harvesting from a wide set of experiences regarding the biotic and technological dimensions of growing food. Regarding the latter, one demanding aspect of this process of adaptation is the modification of the machinery and equipment to adjust to the same width. In the case of the Klompe farm this width corresponds to 3 meters due to the width of the combine. This is implemented along with the use of Controlled Traffic Farming, an "in-field traffic management strategy in which the crop zone and traffic-lanes remain permanently separated" (Gasso, 2014: 175) to reduce soil compaction. Moreover, the equipment used needs to be compatible with having adjacent crops that may not be harvested at the same time. This means that the produce should stay within the lane instead of been placed at one side of the equipment, as is the case for the onion, potato, and carrot harvester, among others. Additional to this tinkering of the equipment, which is one of the most recent adaptations they have gone through, it is

Figure 4 – Strip cultivation in the Klompe Farm (Author, 2021)

Figure 5- The Klompe Farm
(Author, 2021)

important to consider the initial implications in productivity that the adoption of the rest of the regenerative practices have. To recover the poor soil structure that resulted from years of conventional practices, they implemented no/low tillage for protecting the biotic elements in the soil. However, during the process of improving the soil structure they experienced a decrease in yields as the growth of the crops was hampered due to the competition for resources with the cover cop and the low penetration of crops' roots. Also, the use of crops with less economic value such as wheat increases the costs that are associated with strip farming. Furthermore, the spatial implications of the adoption of this technique are not minor. Narrow strips not only imply that machinery needs to transit more over the field when performing every task, it also implies that an area at the end of every lane must be reserved for manoeuvring. When this area is added to the one of the biodiversity lanes, it means that 10% of the plot is unavailable for cultivation. This is particularly important when the cost of land can reach €100.000 per hectare, as is the case for the Klompe farm. Although this project received subsidies to make this transition possible, it raises the question of what would be required for a wider adoption of these practices.

Making up for the additional costs

The additional costs derived from the implementation of RA and SC led Mellany and Jeroen to explore alternatives that increased the returns of their operations. For this reason, they integrated the oats, wheat and soy produced in the farm into the supply chain of high-value-added products. Oats are sold to a producer that is willing to pay a price premium for a local and sustainable product, and wheat and soy to a producer of gourmet soy sauce called Tomasu. The price of 200 ml of Tomasu is around ten times more than a regular soy sauce, which allows the producer to cover the additional costs of the soy and wheat from the Klompe farm. However, cost is not the only restriction the Klompe farm faces. Conventional buyers demand the traceability of the inputs they include in their value chain. This implies that the use of certified seeds is required, which is not in line with regenerative practices. These practices include the use of seeds that have been grown on the field as these are the ones adapted to the conditions of the farm increasing their natural resilience. This is not necessarily the case with imported seeds which are massively produced. Besides, the wheat varieties used in the farm are the result of over 50 seed families from the WUR seed bank as they needed to select the ones with the highest concentration of amino acids to achieve the best flavour in the final product. This makes seed certification a challenge in their case. Therefore, the buyer must be aligned with regenerative practices to accept this condition and to sell a finished product so that this certificate is not demanded in a further stage of the production process. Though it might seem contradictory, another implication of this practice is that the farm cannot sell its produce to buyers that have certifications like Planet Proof or Global Gap regardless of their positive impacts, as these buyers have the same restriction.

While the Klompe farm has established a business model that allows them to compensate the costs of SC through the integration to value chains with high added value, this does not imply that it should be the case for every producer that chooses to adopt these techniques. One of the factors that determines the importance of this integration is the price of the land. According to Mellany, "the economic feasibility in the area where [they] are currently located is reached with €3,000 per hectare, but in other areas in the North or far in the East of the Netherlands where soils are sandier, that level is reached at €1,300 or €1,400 euros". Accordingly, the scarcity and the corresponding high cost of land in the Netherlands demands high yields to maintain the profitability of the project. This is a driver for Mellany and Jeroen to use precision agriculture to increase their productivity through informed decisions derived from the increased monitoring. Precision agriculture allows them to offset the variability of the soil and take more informed decisions based on data and on the documented results of previous harvests, among other indicators. Thus, digital technologies help mitigating risks of the operation.

The high profitability required to break-even and the need of covering the costs related to the transition and the operation of a less efficient system led to the exploration of complementary sources of income. As the benefits from implementing RA go beyond the performance of the cash crops, the leaders of the project launched SH Operations with the goal of estimating the ecosystem services derived from the implementation of regenerative practices. According to Wratten (2013) ecosystem services "include such processes as biological control of pests, weeds and diseases, pollination of crops, amelioration of flooding and wind erosion, provision of food (including fisheries), the hydro-geochemical cycle, capture of carbon by plants and by soil and providing settings for much of the world's tourism" (p.xvi). In the case of Soil Operations, they focus on carbon capture. This is meant to create an additional source of income for farmers, monetizing the environmental advantages of this technique. This requires a strict measurement of soil characteristics through on-farm measurements, satellite images and data processing, associated with the practices performed by the farmers. The aim of this is to become as independent as possible from the reports of farmers and to rely more on data. This provides greater reliability, transparency, and traceability to the corresponding certifications. Hence, data becomes a common language among different sectors to validate transactions that complement farmers' incomes. At the moment of the interview (September 2021) there were five farmers that had started monetizing ecosystem services in five different countries. Three more were interested in the United Kingdom, and other four in the Netherlands. Additional trials were being discussed in Belgium, Turkey, as well as with companies that wanted to engage with soil ecology. Although the interest in this model is increasing, for Leandro "there is a bottleneck, the reduced number [of companies] that are willing to buy these certificates".

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The visit to the fields of the Klompe Farm and the conversations with Mellany and Leandro showed me the wide array of possibilities that can arise from working the land under competitive pressures and environmental restrictions that push innovation. Such a contrast with my understanding of Latin-American peasant agriculture made me understand why Mellany used the term entrepreneur to characterize herself. This difference became even clearer when this term kept on being raised during the interviews that followed. For de Lauwere (2005) Dutch farmers fall into the category of entrepreneurs as they are cost-effective, "'movers of the market', 'innovators', and/or 'discoverers of profit opportunities'" (p. 229). The author identifies four main categories of agricultural entrepreneurs according to personal characteristics and strategic orientation. These categories are prudent farmers, traditional growers, social farmers, and new growers. The last two categories are characterized for being "enthusiastic about new opportunities and possibilities such as diversification (new branches), products with a high added value (regional products, organic farming), nature and landscape" (p. 234). However, while new growers are characterized for being both growth and socially oriented, social farmers are mainly socially oriented. Based on this, the Klompe Farm would fall in the category of new growers as they are continually exploring alternatives to increase farm profitability through different revenue streams.

The diverse and complex set of activities that comprised the operations of the Klompe Farm made me understand that they were outliers among the Dutch agricultural entrepreneurs. Therefore, the interaction with participants of the NPPL project complemented this experience by demonstrating how entrepreneurs with less experience with SC and regenerative practices would experience the process of adaptation.

3.2. The NPPL project for SC

The NPPL is mainly an application project, which means that the technical experts involved are not aiming to do research but to work together with farmers and technology suppliers in the application of digital techniques that are available in the market. The goal is to make the introduction of these technologies as smooth as possible and to identify the potential challenges that may arise from their operation on the field. This has led farmers and researchers to encounter compatibility issues that have not been identified before. When they discover such issues, they proceed to map the barriers that keep farmers from applying these technologies in their farms to explore long term solutions based on them. For Koen van Boheemen, one of the interviewed technical experts from WUR who is involved in this project, the main challenge that farmers have is that there are many companies that offer technologies that claim to fulfill their needs. For farmers however, it is not always easy to assess which technology can add value to their farms. Hence, farmers require a better understanding of how these technologies work. NPPL helps them evaluate how different technologies fit in the farming system that is in place at their farms. This is done through advice work, but also by working along with farmers to solve the technical problems that arise in the process of adoption. This process helps to establish a dialogue between the companies that offer the technologies and the farmers who want to know if the equipment offered is going to work on their fields.

Three experiences on the field allowed me to know the NPPL project first-hand. These events consisted of demonstrations of precision agriculture technologies for arable farming where the farmer who hosted the event shared his experience implementing such solutions. It was noticeable that women were only a small percentage of the participants to these events, a lower percentage than in agriculture in general. While two of these events were not specifically planned for the implementation of strip cultivation, they served to introduce me to the technologies that were being used for it. Some I had already encountered in the Klompe Farm, such as the variable sprayer, the use of satellite imagery and remote sensing. The first event I visited was in Andijk (N. H.) at the farm of Stef Ruiter-Wever, a flower grower that already had seven years of experience with precision farming but was testing more sophisticated technologies. Among them were soil sensors, deep vision equipment for disease detection, and variable sprayers. As an introduction to the event, a WUR researcher introduced the general aim of NPPL. He explained that the project is "not only about the hard technology, but also about how [to] use knowledge about agroecology in precision farming". Then, adding how the experiences with other entrepreneurs who also adopted technologies in their farm had been being registered and shared with the public through news, magazine articles and online content. The event continued with an intervention where it was the farmer (and not the researcher), the one who explained the adoption process, the challenges, and the results he had gotten so far (Figure 6). This day shed some light about the way technology interacts with farmers and researchers while on the field, and the way that the acquired knowledge was being owned and shared.

The questions from the audience were aimed to discuss the efficiency gains in the use of crop protection products with variable rate application, and the way that the input data was gathered and how it affected the scheduling of the activities in the farm. These questions made me think about the concerns of farmers who wanted to implement strip cultivation. Though through different means, the questions revolved similarly around the extent to which SC can effectively contribute to the reduced use of products for crop protection, about the data that is important to monitor crop performance, and the implications in the scheduling and definition of the rotation plan (Tholhuijsen, 2020, 2021). Still, the fact that these farmers ventured into the adoption of an alternative growing technique implies that the underlying imaginaries (Sippel and Visser, 2021) relate to elements that extend beyond what can be answered through these questions. This will be explored further in the next section.

Figure 6 – Stef Ruiter (right) answering the questions from WUR researcher Koen van Boheemen (left) and assistant farmers. Source: (NPPL, 2021)

Characterization of the entrepreneurs

The diversity of backgrounds of the participants not only corresponds to the objective of the project of exploring the adjustments required for a successful performance of SC under different conditions and regions but resembles the multiple possibilities that fit within this technique. Appendix 2 contains a characterization of the five participants and showcases how dairy farmers, arable farmers, and soil consultants with different levels of experience with digital technologies coincide in these trials. Such diversity is also evident when looking at the ways entrepreneurs are adopting SC. While Cornelis Mosselman has opted for strips that are 3.2 meters wide aiming to benefit from the increased biodiversity on his plot, Remco Wesdorp (arable farmer) and Huibert Groeneveld (cattle farmer) collaborate for closing the cycles of their operation while opting for strips that are 20 and 40 m wide. When asked about this decision, Wesdorp says that:

> "We want to stay as close as possible to regular agricultural practice. That is why we choose, for example, a strip width between 20 and 40 meters, so that no special machines are needed" (van Lier, 2021)

Regarding their joint venture, Groeneveld adds how the use of particular cover crops benefits them both:

> "The advantage is that these crops fix nitrogen in the soil and form an extremely good condition (voorvrucht) for arable crops. And by growing protein crops locally that can serve as animal feed, we as a dairy farm need to buy less roughage and concentrates. We then close the cycle by applying our manure to the arable fields" (van Lier, 2021)

They expect that within six years they will reduce the use of insecticide and fungicide substantially, as well as to stop relying on artificial fertilizers. The complementarity of the motivations of these farmers to get involved with SC showcases the multiplicity of factors that coincide in the planning of their operations. From the technical fit of their technique and their machinery to the long-term implications of their decisions on the soil. Theo Nieuwenhuis, as a soil consultant, shares these concerns as he is convinced of the importance of soil biodiversity and structure. That is why he plans on using minimal tillage and herbal mixtures between the crops for natural pest control with predators such as ground beetles, ladybugs, and parasitic wasps. Hence his willingness to get involved with this project. According to him, "strip cultivation fits in seamlessly with these principles" (NPPL, 2021). By doing this he is anticipating on the effects of future regulations and of consumption trends. In his own words:

> "I see no future in food production using fertilizers and chemical pesticides. Public support for intensive food production is disappearing" (NPPL, 2021)

These anticipated restrictions imply that alternatives to the most pressing problems have to be found elsewhere. Among the most pressing needs are soil compaction, increased weather variability and evermore restrictions for water use in agriculture. Around 60-70% of arable land on clay in the Northern Netherlands has soil compaction. From these, the organic farmers and adopters of SC are among the less affected by this issue (Wouda, 2019). For Nieuwenhuis, one of the factors that help overcome this is increasing the percentage of organic matter available on the soil, as an additional 1% of it implies that additional 300,000 to 400,000 litres of water can be retained in the soil per hectare which implies a lower need for irrigation (van Cooten, 2021). This aspect is particularly relevant when adopting SC as irrigation has turned out to be a significant challenge in the process of implementation. The proximity of crops with different water needs has made Nieuwenhuis ask himself three questions for which precision agriculture is expected to have an answer, "how do you give the right amount of water at the right time in the right place?" (NPPL, 2021). While he considers a drip irrigation system as an alternative, the farmer Mosselman who encountered this issue himself, has taken distance from this option. From his perspective drip irrigation is not enough for germinating seeds and it does not allow for selective irrigation within the strips. For the 2022 season he will make use of two moving irrigation systems (*beregeningsbomen*) (van Houweling, 2021). On the meantime, he has gone through a process of tinkering on which he designed a water irrigation truck of the width of the strips to fulfill his needs in the meantime (NPPL, 2020).

These challenges have emerged while the entrepreneurs still are trying to maintain their farm profitable and adjusting to the changes in the commercialization of a broader portfolio of products. Although Nieuwenhuis was advised to ensure firm agreements with buyers before transitioning to SC, he has already faced the consequences of market variations, he states that:

> "The sales of organic vegetables are growing less than expected and hoped. Existing growers are given priority. That is understandable, but for me a setback. Still, I will persevere, probably with fewer crops than I had planned at the beginning of this year." (NPPL, 2021)

Changing the revenue model is a challenge that entrepreneurs must face, this adds to the financial uncertainty of incurring on additional investments on equipment but also in terms of the reduced efficiency during the transition. For Mosselman, during the first years the costs outweigh the benefits, even with the existing support with discounts on loans and reimbursements from the Common Agricultural Policy (CAP). He qualifies them as "a drop in the ocean, (…) not at all in proportion to the risks and extra costs that pioneering entails" (NPPL, 2020). For this reason, he considers that if the increasing regulation is meant to incentivize practices as SC, more support should be made available for entrepreneurs. In the meantime, Mosselman has opted for short supply chains to increase his revenues. The reason behind this is that for him organic food alone is no longer sufficiently distinctive, and it has become increasingly more volume oriented (van Houweling, 2021).

With the aim of achieving this, Mosselman decided to implement strip cultivation even before knowing about the experience that WUR had built on the topic for several years. When he found out about this, he thought: "then they know how to do it. But that was disappointing. In practice, much remains to be discovered" (van Houweling, 2021). Hence, Mosselman opted for learning from doing while being informed by advisors who could add some perspective to his process. For him, waiting for the results of the research would simply take too long. However, the gap between the academic knowledge and the practice on the field is not exclusive of these two sectors. Manufacturers still have gaps to close with practice as their solutions do not apply still to different farmers' realities. For this reason, Jacob van der Borne, the most experienced participant with digital technologies, recognizes that "You can't buy smart farming, you have to do it yourself" (Tholhuijsen, 2020).

The experience of the researchers

In Andijk, during the first demonstration that I already introduced, I had the opportunity to interact with Koen van Boheemen, one of the WUR researchers assisting the farmers in the frame of the NPPL project. He was hard to reach, he was constantly surrounded by farmers who shared their experiences with him to get feedback and to know a different perspective on what to do on their fields. Close to the end of the event I got to introduce myself and the purpose of this research, to which he generously agreed to contribute through a couple of videocalls. With this image in mind, I asked him about his relationship with the entrepreneurs of the project, more precisely if he felt that his position as a WUR researcher placed him as an expert with knowledge that is more valid than theirs. He responded frankly:

> "Some farmers believe that I am in a higher level in this hierarchy because I come from Wageningen, and I find this more difficult because I am a human being that doesn't have all the answers to all the questions. (…) I'm telling the farmers to see me as a friend or as a neighbor farmer with whom you are discussing your options and ideas, and then we will come up with something."

In this way, he has been able to work with the entrepreneurs on finding technical solutions to the different activities for crop maintenance. The need to change from working with equipment with a 40 m range to three-meter-wide applications has made him work on the configuration of different seeding machines to optimally distribute the rows of crops in a field, on the corresponding mechanical weeding process, and harvest. However, this does not mean that they are creating solutions that can be generalized to every farm. They go through a process of tinkering (Higgins et al., 2017) of existing machines. Fully developing a new equipment is too demanding on time and costs for a farmer. In van Boheemen's words, "first we need to get to a base level where we can make everything and then we need to get to the optimization level, but we're not there yet". Still, this does not imply that the knowledge created through this process remains at a farm level. The NPPL project purposefully opens spaces in specialized media where farmers share their experiences and thus inform the public on the progress, the challenges, and the solutions identified.

As it is too expensive for farmers to develop new equipment, WUR has destined a testing area for these solutions. In the Boerderij van de Toekomst (BvdT), located in Lelystad (Fl.), a team of researchers and technology developers coincide to explore the extent to which a comprehensive portfolio of digital solutions can lead to a more sustainable way of farming. On the third encounter I had with the NPPL demonstrations, a set of developers met for showcasing projects of robotization and train path mechanization (See Figures 8-11). These technologies are being tested there for SC, although they can be used in monoculture settings as well. The main reason for their size is to reduce the compaction levels that large machinery generates when going across the fields. Although around 200 people attended this event, only a limited number were farmers or contractors. The majority were researchers, consultants, manufacturers, mechanization companies and students (NPPL, 2021). When testing the equipment, it became evident that not all of the applications are ready to be used/ready to function on every field. First, it was not possible to test the AgroIntelli Robotti (Figure 9) with an adapted haulm topper as its depth control was not functioning properly. Second, the cultivator that was installed on the AgXeed Agbot (Figure 10) got clogged with mud due to the uneven and wet heavy soil. The persons in charge of the demonstration confirmed that when working on lighter terrain the equipment had performed successfully. These events turned the assistants very critical from the developments shown, which "is also a sign that it is still far from clear in which direction robotization but also scaling down will develop in the future" (NPPL, 2021).

To better understand the progress achieved so far by the researchers at the BvdT, I approached Koen Klompe to talk further with him. Over a videocall the following week, he shared some of his perspective as an organic farmer and his experience as a researcher on SC. He was swift to state that SC has led to less results than expected. Recently, they were not able to harvest carrots, nor potatoes from the field. The former because they were planted by the side of grass clover where rodents found a place to hide after feeding from the carrots. The latter due to a Phytophthora affectation in the plot for which the strips were not effective to contain the spread to other lanes. For Klompe, this was due to a mix of factors. First, the weather conditions made the pressure of the fungus too high as the year has been wetter and warmer than expected. Second, the use of resistant cultivars led them to use a threshold for deciding the moment of application of crop protection products, but this took place slightly late. Thirdly, the creation of micro-climates due to the proximity of tall and low crops did not allow for air to flow as before, creating proper conditions for the spread of the fungus on low crops. Nonetheless, he still considers that it is too early to know if SC should be promoted or dismissed. The greatest challenge he identifies comes from the planning and the disposition of the crops in the field. The significant number of factors that inform the decision of defining neighboring crops leads him to conclude that "you will never have the perfect rotation". To inform this decision the make use of the software NDICEA, a model that offers an "indication of the nitrogen dynamics and organic matter dynamics" (Louis Boolk Instituut, N.D.), as well as ROTAT which was "designed for generating crop rotations based on agronomic criteria in a transparent manner (…) [through] filters [that] represent expert knowledge in a quantitative and explicit way" (Dogliotti et al., 2003). Nevertheless, Klompe recognizes that "technology is not yet far enough for defining tasks in detail per strips". The distance between the objective of certain solutions and the results obtained when integrated into various operations on the field is still significant. Regardless, new robotic solutions continue emerging to fill this gap. That is the case of the developers introduced in the following two sections.

Figure 7 – Tractor with adjusted width of the axis
(Author, 2021)

Figure 8 – Adjusted two-row potato harvester
(Author, 2021)

Figure 9 – Autonomous implement carrier Robotti 150D (Author, 2021)

Figure 10 – AgXeed AgBot Tracked tractor equipped with a cultivator and a visual yield measurement system. (NPPL, 2021)

3.3 Pixelfarming Robotics for a biodiverse agriculture

The second demonstration of digital technologies for agriculture took place in Jacob van den Borne's farm in Reusel (N.-Br.), one of the participants of the NPPL project who also has a training and experimental institute for drones and precision agriculture. This event served to showcase equipment for large scale conventional farming, decision support systems, different on-field sensors and a set of robotic solutions. After approaching the stand and talking briefly to one of the engineers involved in the development of Robot-One, I had the opportunity to meet Arend Koekoek, the CEO of PR. Although I had already read about his company, our conversation confirmed his alignment with the principles of biodiverse agriculture and his aim to contribute to its materialization. Pixelfarming Farming is built upon the concept of 'digital vegetable gardening' without the use of chemical pesticides. To achieve this, they have built Robot-One, a smart agricultural robot for biodiverse farming designed to perform different tasks. On its ten robotic arms, tools like hoes, cultivators, harrows, and spits can be installed. Currently, it is better adjusted to perform weed control. They are in a beta phase with real clients for which they can offer a robust solution. That is not the case when used in more biodiverse farming, when different crops are withing the same lane.

Koekoek, previously an entrepreneur in the sector of logistics, made a sector shift to work in agriculture to contribute to the materialization of a fully circular food world. Thus, he decided to get a farm to better understand the challenges faced by successful entrepreneurs who make this transition. This farm became Campus Almkerk, a regional innovation campus with workspaces, labs and testing grounds for agriculture based on biodiversity, nature-inclusive agriculture and sustainable construction and energy concepts, among other things. In this space he recognized the importance of addressing weeding. It is a key factor as it is a very laborious task that is essential given that "the types of plants that we want to consume as humans are not the strongest ones. Weeds are typically stronger". Moreover, an autonomous mechanical solution would replace the need for herbicides which are increasingly becoming more restricted.

> "The trick is trying to harmonize and to exchange knowledge and ways of working. And embracing technology because it is necessary to make the next step. To make the bridge between what we eat and how to increase our wealth, which has to do with technology" – Arend Koekoek

Figure 11 – Robot One, solution designed and manufactured by Pixelfarming Robotics (Author, 2021)

3.4 Trabotyx

By the end of the event in Reusel, I approached Tim Kreukniet the CEO of Trabotyx. He was presenting his prototype, a weeding solution for organic farming. The decision to focus on weeding came from interviewing over one hundred farmers to validate their needs and priorities. As the event was about to be over, we arranged a meeting in their offices in Leiden a couple of weeks later to discuss further about the project along with Mohamed Boussama. There, Kreukniet told me that initially the plan was to develop a solution for disease and pest detection. Given that their early detection could save up to 20% of yield loss, they thought that they were headed in the right direction. However, farmers did not find substantial value from this solution. As Kreukniet characterizes them, farmers are *crisis managers*, they only have short periods of time to perform laborious tasks in the field. Changes in the meteorological conditions or any issue with inputs and equipment mean that activities are being delayed on a packed schedule of activities for crop maintenance. Thus, what agricultural entrepreneurs value the most is having more time available, and a solution for disease detection does not offer that. Conversely, a weeding solution would replace manual labour which is expensive and difficult to get. According to Kreukniet, manual weeding represents up to 50% of the operational costs of organic farmers, they pay between €2,000 and €3,000 per hectare per year for it. Such a high cost creates an opportunity for innovators. However, this is not the case with conventional farmers as they only spend around €400 for this, with which it is hard to compete. Their solution is aimed to weed one hectare per day, replacing the work of four people.

"As a start-up we need to be painkillers, not vitamins" – Mohamed Boussama (CTO)

Figure 13 – Weeding robot designed by Trabotyx (Author, 2021)

Chapter 4
Interacting land imaginaries

As it became manifest in the previous chapter, there is a great diversity in the ways farmers, developers and researchers experience the transition towards a more sustainable agriculture. Their interaction with land through different technologies opens the possibility to a redefinition of their understanding of soil, crops, and farming practices (van der Velden, 2019). In this chapter, these experiences will be analysed using the concept of land imaginaries to unpack the overlapping environmental, sociotechnical, and spatial imaginaries that constitute them (Sippel and Visser, 2021). Thus, exploring the process through which existing imaginaries are extended and translated to take roots and flourish in new soils, along with the frictions that emerge in the process (Jasanoff, 2015). Such frictions will be explored at the farm level, the institutional level, but also considering the market pressures that influence the decisions of entrepreneurs and their interaction with other actors and technologies.

4.1 Soil imaginaries

Land gets its symbolic value from its "features of (high degrees of) fixity, a reservoir of manifold resources, its capacity to constitute a renewable resource, and above all its life-giving capacities" (Sippel and Visser, 2021: 275), which changes across societies, space, and time. The landscape in the Netherlands exemplifies these changes in a very material way. Through a long history of land reclamation from the sea, the land was shaped to fit the hegemonic sociotechnical imaginary of agricultural production. This imaginary that is embodied in conventional entrepreneurial farming has become deeply engrained (van der Ploeg, 2020) and interacts with the pursuit of alternative futures. Uniformity, efficiency, and timeliness became part of farmers values. This came up with Koen van Boheemen from the NPPL project:

> "I grew up in what is called the Polder. Where everything was made on a drawing board, where everything is square. And I love seeing in springtime all the fields being seeded, and then all the fields turning green. For me, strip tillage looks less tidy than a field with only one crop. It doesn't look more natural to me, even though it might be" – Koen van Boheemen (WUR Researcher)

However, as the impact of conventional agriculture becomes manifest in the high compaction levels and the subsequent low water retention, on a decrease in the availability of micronutrients for plants, and in the loss of biodiversity above and below the soil, these imaginaries start to change. Given that land imaginaries "encompass the various social understandings of what land is (…), and ideas of what it can, or should, do in society" (Li in Sippel and Visser, 2021: 274), it is important to track how land's *social affordances* evolve in time under different pressures. This change takes place unevenly and even beyond the fields, to the point that a technologist formerly dedicated to logistics came to realize that:

> "We have very professional farmers in the Netherlands who are doing a very, very good job from a volume perspective. But the way we remove the crops from the fields at one time, leaves no room for biodiversity" – Arend Koekoek (PR)

Nonetheless, this change does not happen seamlessly, nor does it go uncontested:

> "I don't see a limit to monocultures. We have a lot of tools to keep our monocultures happy and healthy. But when we think of systems where we are not allowed to use chemicals anymore, then the answer is yes. The fields should be small to keep the diseases to as little area as possible" – Koen van Boheemen (WUR Researcher)

The persistence of conventional farming practices should not be reduced to an unwillingness to change. On the contrary, it points to "the structural path-dependency and other mechanisms that lock these farmers into the dominant socio-technical regime" (van der Ploeg, 2020: 602). This persistence is rooted in both, material needs and ideological considerations. The former includes high financial costs, and a vulnerability to cost increases and price decreases, while believing they have the moral right to *feed the world*, even surpassing ecological limits as they might be compensated for elsewhere. While the projects presented are subject to such material pressures, they act upon different ideological considerations. The opposition and resistance to such pressures stimulates the creation of new sociotechnical imaginaries that have the potential to lead to far-reaching reforms (Jasanoff, 2015: 337). Thus, the implicit changes in the scope of agriculture to include a greater focus on biodiversity, lead to alternative practical engagements with land and become an explicit driving force of land transformation.

In the case of SC, farmers, technology developers and researchers work together to explore viable alternatives for biodiverse agriculture while being subject to significant market pressures. Among them, the high prices of land relative to other European countries and one of the highest debt levels internationally (Melyukhina, 2011: 23). This has led to an expansion of the potential of soil as a key input that is not only life-giver, but a habitat with the potential of increasing productivity, crop resilience, and mitigating climate change through carbon capture. However, these goals imply the interaction of multiple factors (e.g., soil characteristics, weather, cover and cash crops) that require technical and experiential knowledge for implementation and monitoring. Mellany Klompe, exemplifies this when she says:

> "We have gotten different growth rates between soy strips depending on the cover crop that was used before. This was verified by remote monitoring and biomass detection" – Mellany Klompe (Soils Heroes)

Such a technical approach to agriculture has led to an increasing knowledge about the soil which is becoming available for farmers to adopt SC. Although the importance of a healthy soil to achieve this is recognized by the different participants, it is also important to point out the different approaches they have when working with it. For instance, Appendix 3 points how Barberi from SH and Koekoek from PR have a similar conception of what 'good farming' is, while prioritizing different elements to achieve this objective. The higher involvement that Leandro has with soil and its complexities, makes him value the technical understanding of this factor as a determinant for a proper agriculture. This leads him to explore which are the crop rotations that ensure the best balance between biodiversity, yields and profitability. Alternatively, Koekoek focuses on technology as an enabler for achieving biodiverse agriculture. He not only perceives in technology as an alternative to mitigate cost pressure of the higher labor intensity, but also a means to address the increasing operational complexity of managing multiple crops on the same field. This approach allows him to picture an ideal agricultural landscape that consists of "food gardens (…) [with] 100-150 crops per field". Conversely, farmers from NPPL and even in SH, experience a trade-off when working with different crop mixes to have the best results from SC while experiencing complex task planning and crop programming. Thus, different ways to engage with the soil coincide with the objective of transitioning towards a more sustainable agriculture.

In the fields of the SH Foundation highly technical knowledge and a focus on biodiversity coexist to achieve robust findings that create greater trust among farmers about SC. By promoting regenerative practices among farmer's networks, SH is promoting an expanded understanding of nature that aligns to the interests of entrepreneurs to mitigate environmental and economic challenges. Leandro broadens the reach of farming by comparing SC with precision agriculture.

> "There is an overlap *between these two technologies*, you could implement precision agriculture within strip farming. With precision agriculture you're changing the doses you use depending on the quality of the soil, with strip farming you could do the same" – Leandro Barberi (SH)

By recognizing the broader potential of the soil over the growing process, and exploring the way different variables interact, SC becomes a technology capable of achieving similar results as chemical fertilizers, and crop protection product, though through more sustainable means. Characterizing SC as a technology, along with its complementarity with precision agriculture, is in line with the definition by MacKenzie and Wajcman of technology as "the integration of the physical objects or artifacts, the process of making the objects and the meaning associated with the physical objects" (cited in Wahab, 2012: 62). Thus, soil becomes a technology by associating an additional meaning to elements like cover crops, to include their faculties of carbon capture, nitrogen fixing, and for the improvement of soil structure. This same understanding of SC is also applied by Arend Koekoek:

> "We are starting a program we call Smart Biology. It is a research program on how to apply smart technology to biology. And vice versa. How do you make smart plant combinations, which are not silicon-based technologies, using Ai to reduce the need for artificial chemistry" – Arend Koekoek (PR)

Such a data-oriented approach points out the blurry limits between digital and non-silicon-based technologies as they inform each other's process of transformation. Moreover, a three-way process of domestication takes place (Finstad and Egseth, 2021) when analyzing the ways that farmers adapt their farming practices with SC, the way the landscape and the soil change in accordance with this, and how digital solutions adjust to the new parameters. The increasing reliance on data to inform the 'liveliness' of this interaction, point as well to new ways of using information while redefining what a *good field* looks like, and what *good farming* means (Ibid.: 217). The mutually informing process between both technologies show the overlapping of soil imaginaries and sociotechnical imaginaries (Sippel and Visser, 2021), as an expansion of the first has also responded to a change on the second. Still, these complex dynamics of transformation of agricultural practices indicate that digital technologies are only one component of the process, others being advisory networks, new relations with consumers, new policies supporting open innovation, and farm structure (Schnebelin et al., Forthcoming). This complexity comes up in the monetization of ecosystem services based on the estimations of SH Operations through on-farm measurements on fields in different countries, satellite images and data processing, and associating them with the practices performed by farmers.

> "The aim is to become as independent as possible from the reports of farmers and to rely more on data. This, to provide greater reliability, transparency, and traceability to the corresponding certifications. Data has become a common language among different sectors to validate transactions that complement farmers' incomes" – Leandro Barberi (SH)

The interrelation between data, farming and soil, within a broader context of a climate crisis, shows how the value articulation around ecosystem services is embedded in social, cultural, and historical processes (Ernstson and Sörlin, 2013). Therefore, soil and data become complementary to farmers' navigation around competitive pressures and the "marketization of ecological complexity" (Castree in Ernstson and Sörlin, 2013: 282).

4.2 Evolving socio-technical imaginaries

"You need precision agriculture for strip farming" – Mellany Klompe

The technologies to estimate and monetize ecosystem services, and for the mechanization of SC, are not necessarily new designs. These digital solutions are based upon an established technological system, even if they come from a sector different to agriculture. This is exemplified not only in the offer of certificates to offset emissions which were initially related to forestry and resource management, but in robotic solutions whose precursors are far from the fields. Just as SC competes with conventional practices to create greater value for farmers, solutions like the ones of PR and Trabotyx coexist with an offer of technologies that is optimized for large-scale production and is rooted in the current farming model. For farmers, the configuration they currently use not only implied a significant economic investment but created a sense of familiarity, a technological lock-in (Clapp and Ruder, 2020) from which it is difficult to deviate. Thus, the materialization of SC as an alternative implies a new process of embedding, which is material as in technologies, and is psychosocial through the values and priorities that sustain farmers' engagement with the soil (Jasanoff, 2015).

The cases presented show that technology plays a key role in allowing farmers to navigate through the pressures and constraints they face from the market and from the conditions on the field. Nevertheless, as the technology offer is in the process of consolidation, the expected value from it differs among the participants to a certain extent. This was introduced previously when analyzing Koekoek's (PR) relationship with soil and how it intersected with his perspective of the role of technology. By perceiving the latter as an enabler for more sophisticated farming practices, he aims to expand the approach entrepreneurs can have towards their craft. For him, technology has the potential to create business models with shorter value chains that bring consumers closer to the food they consume through streaming on the field, and crop mixtures adjusted to each individual. He sees Robot One as a hardware that has the potential to increase revenue by opening a door to numerous possibilities for farmers to decide from. For Koen van Boheeemen (NPPL), and Leandro Barberi (SH), transparency is a key feature that can be achieved through technology. On the one hand, it would allow buyers and consumers to have greater traceability of the produce by knowing the inputs and the techniques used to grow it. On the other, measurements over the impact of the production process on the soil, and on the environment in general, would allow for a greater trust on revenue streams as ecosystem services while increasing the accountability of farming practices. While for Kreukniet (Trabotyx) and the organic farmers he interviewed, the main value comes from the mitigation of labor stress through automation. Lastly, farmers involved in the NPPL project express how technology is a mechanism of risk mitigation by allowing them to perform the correct tasks, at the correct moment, in the correct way. This needs to come from a sense of reliability and robustness to adjust to the different conditions that are present on the field. Such a wide array of priorities and expectations feed the process of materialization of the solutions available and to come. Hence, it is the set of imaginaries that shape technology which allows farmers to navigate the wide range of pressures they face, and which redefine what 'good farming' will look like.

Nonetheless, the extension of these alternative imaginaries implies frictions as they are laid upon existing economic, material, and social infrastructures. This should not lead to disregarding the role of current solutions in the process of transitioning.

> "The current digital equipment for conventional agriculture is necessary. I am glad that these very big chemical sprayers are out there because if I had to build 30.000 robots which we need in the Netherlands, I cannot build them" – Arend Koekoek (PR)

Such reliance on current technologies is not only coming from the need to satisfy an unmet demand, but from the role they play in the transition towards a more sustainable agriculture. Technologies as precision agriculture have served to start addressing the need to reduce the residues and impacts produced by conventional agriculture, while increasing farmers' proximity to a new set of digital technologies. Precision agriculture has served for the extension of monocultures, and has allowed informed monitoring and planning in SC, as exemplified in the Klompe Farm. Furthermore, there is a degree of complementarity between the current digital equipment and the new solutions that are emerging. For Tim Kreukniet, this complementarity manifests as well in material ways.

> "Farmers are used to standard dimensions and methods so it's easy to build something for them" – Tim Kreukniet (Trabotyx)

This showcases how new imaginaries, and their corresponding materiality, are built on pre-existent ones and how they have the possibility to become an explicit and conscious driving force of land transformation (Sippel and Visser, 2021). Addressing these partial synergies serves to identify the relevance of technology to achieve particular results in agriculture, nonetheless it points out as well that more is needed for embedding a more sustainable agriculture. To achieve this, "the technology itself only plays a minor role[, w]hat is more important is the realignment of the system in which the technology is placed" (van der Velden, 2019: 9). This includes the physical environment, institutions, and knowledge that are shaped by and shape the technology. As the previous section already addressed the physical environment, the following will address some of the frictions that arise at an institutional level.

Institutions in transition

Institutions stabilize the sociotechnical imaginaries that are collectively held and publicly performed (Jasanoff, 2015). Therefore, when these imaginaries evolve and become more widespread, institutions adjust progressively to the new visions that are attainable through advances in science and technology. In this case, such adjustment has served to the extension of digital technologies to agriculture (EC, 2021), and to the quest for a residue-free process for growing food (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2020). The potential of these policies to shape future trajectories is such that farmers as Mellany Klompe recognize in the CAP a vehicle to mainstreaming SC.

> "The CAP has the faculty of creating important incentives for implementing sustainable practices as SC. (…) It is important for regenerative practices to get significant [Eco-Scheme] points but especially for the most complex tasks as lane farming. This is directly aligned with economically feasibility" – Mellany Klompe (SH)

However, these instruments also create a source of friction for both, the hegemonic entrepreneurial farming (van der Ploeg, 2020), and the *new growers* (de Lauwere, 2005) that aim to adopt a more sustainable agriculture. This friction comes from disregarding the market pressures to which entrepreneurs are subject to and the corresponding lock-in that they imply.

> "There is a detachment of policy makers from reality. The gap is that the farmer feels that environmentally he must do a whole load of things but on the business side he can do less and less. (…) So, farmers are stuck because prices are also under pressure" – Tim Kreukniet (Trabotyx)

It is among the tensions between policies that aim to promote certain ways of farming, and the thin profit margins from a highly competitive sector, that technology developers steer to add value to the farmers. In this process, developers challenge the capacity of the institutional framework to adjust to the speed of the uptake of SC and to the offer of technologies that accompany it. This manifested in the NPPL project when entrepreneurs faced the Dutch registration system of crops. This process became particularly complex with SC as it demanded registering each strip, instead of a single block with monocultures. This led WUR researchers to develop a temporary solution through a script that farmers adjusted according to their collection of crops, but also to take this into account in the future development of business management systems and platforms. Similarly, Mosselman's irrigation water truck, which was the result of a process of tinkering, faced a barrier for taking it to the field. It required a technical registration that WUR researchers had to advocate for, to allow its use. In both cases, the legitimacy of WUR in the agricultural sector served as a vehicle to discuss these gaps with the corresponding governmental agencies. Thus, exemplifying the potential of collectively held imaginaries that emerge from a set of challenges on the physical reality to inform farming practices, which are legitimized by research institutions that have the capacity to inform the institutional framework within which SC takes place. As already discussed, this mutually enforcing process is not free from frictions, but nevertheless progressively sets the parameters for an alternative future.

Knowledge interaction

The cases presented exemplify how there are entrepreneurs whose soil imaginaries have transitioned towards a more sustainable understanding of soil and agriculture, but that lack the technologies to implement them under their own socio-technical imaginaries. In the case of SH, they are working on filling this gap by producing technical knowledge based on data analysis and crop monitoring. In this process they not only rely on their own capabilities but have worked along with WUR to determine soil water retention capacities and carbon capture. Similarly, they have worked with the University of Amsterdam to explore the relationship of RA and biodiversity, and are currently working with them on a new project to delve into the relationship between the nutrition level of food and its relationship with soil health. In the NPPL this is even more explicit as farmers work along WUR researchers in the lively process of domestication (Finstad and Egseth, 2021) of digital and non-silicon-based technologies for SC. Finally, in PR they have worked with WUR and HAS Hogeschool to research the effects of biodiverse agriculture on quality and yields, as well as on climate resilience. The close relationship of these three projects with academia denote the current knowledge gap on this topic, and the legitimacy of academic research for informing farming practices. But furthermore, it is important to highlight how in SH and PR the projects have been demand-driven as researcher centers are responding to the request of agricultural entrepreneurs, and the central role that farmers play in NPPL for identifying the issues that are to be addressed. For Mellany Klompe, this is a response to the current offer of agricultural advisors, as these advisors "are tied to particular suppliers that promote conventional practices and aim to increase the use of artificial chemical inputs".

In the transition towards a more sustainable agriculture, the distance between the private sector and agricultural entrepreneurs does not only manifest when the latter explore alternatives to the hegemonic technological offer, but also on the threshold that qualifies a product as ready for use. While farmers have a low willingness to invest in equipment that does not offer a substantial benefit with significant reliability, technology producers are profit driven.

> "Developers built only one application and then they start selling it, they don't worry much about being versatile. They are very happy building something that works and then they want to sell it." - Koen van Boheemen (NPPL)

The high costs incurred in product development in the technology sector are a factor that push producers to launch products swiftly to recover their investment. For van Boheemen, this has been the case with yield mappers that were designed for working with potatoes but have had performance issues when farmers use them with onions or beetroots expecting them to perform reliably. While he acknowledges that the early launch of certain technologies affects their degree of versatility, he also points out that after the first product is launched the speed of adjustment increases. This, as most of the times it is the algorithms that need to be created to adjust to different crops, which tends to be a faster process. In the meantime, the im-precision of some of these technologies create a precision divide (Visser, Sippel and Thiemann, 2021) not only between particular crops, but also among different cultivation techniques as is the case with SC. Moreover, it raises a question regarding the power that companies are exercising in defining the crops to be grown and consequently the diets to be had (Carolan, 2017).

The introduction of digital technologies to agriculture involves power shifts that are already transforming the way farmers relate to the land, their reliance on their equipment, and their connection with consumers. Digital technologies imply a new set of paradigms that Kreukniet (Trabotyx) points out by showing how farmers are "go[ing] from heavy equipment to small machinery, from mechanics to electronics, from massive output to low output; going from big machines that you understand, to small machines that you don't understand". For instance, technologies as the GPS used on auto-steering tractors allow for Controlled Traffic Farming, which reduces the levels of soil compaction while bringing down labor hours. However, the lack of understanding of how it creates a dependency that becomes manifest when a failure in the system takes place. Both, Klompe (SH) and van Boheemen (NPPL), pointed out how a malfunction on the GPS made the tractors go to full stop. For van Boheemen:

> "The problem in farming [with these interruptions] is that you have to do the job when the technical conditions are right. So, you are in bigger trouble than if it happened in a factory. In farms you hardly get second chances that are as good as the initial."

Klompe adds another factor that contributes to this dependence:

> "These technologies imply significant investments for their initial value but also because their lifespan is relatively short given constant innovation. It is also important to be interested in technology, as it can be time consuming and complex."

Thus, as farmers increase their reliance on digital equipment, they experience trade-offs between the value they add, and the transference of power to actor outside their fields. This is both instant when malfunction takes place, but also dynamic as constant innovation pushes farmers into a technological treadmill. A permanent pursuit for increased competitivity by updating inputs and techniques (Levins and Cochrane 1996). Such treadmill not only implies constant investment, but also a constant re-skilling to be able to adequately incorporate new solutions to the operations of the farm. For Koekoek (PR) the lack of this re-skilling is a problem as "the access [to new technologies] is limited just to a few people who understand it". Hence, technology might be adopted mostly by more sophisticated farmers that out-compete those who do not adopt them, potentially leading to higher land concentration.

As the degree of complexity of digital technologies increases, two phenomena take place. Firstly, these solutions become *black boxes* where complex algorithms deliver highly specific information for farmers who not necessarily understand how the equipment produced such data. Secondly, as the level of confidence on these solutions increases, farmers might go into a de-skilling process as these technologies will accurately determine the action plan required for the crops. Van Boheemen (NPPL) encountered the first phenomena when testing a high-spectral camera for disease detection. On the trials the equipment managed to identify an affectation on a potato crop at an early stage, which farmers were not able to identify visually. This made them doubt from the result and test the plants on the lab, where the initial diagnose was confirmed. For him, only by working continuously with these technologies, farmers will start trusting them.

> "For farmers it is very important to have faith in the machines that they are using. So, if someone can explain to them what is the logic behind them, they are quicker to trust them. But if it is a black box, and deep learning is by definition a black box system, this becomes a challenge. Then, if this technology starts showing a strange behaviour – and nobody can predict that because it is a black box – that is a big problem." – Koen van Boheemen (NPPL)

The potential mistakes of these technologies turn the claimed high-accuracy into a precision trap if trusting farmers fail to identify these errors (Visser, Sippel and Thiemann, 2021). On this respect, van Boheemen adds:

> "If we develop deep learning systems that tell you that your crop is not healthy, without you knowing what's going on, you might not take the time to check if the system is correct. Then we become slaves of our computers. Which might not be so bad unless the equipment does not work well."

This statement introduces the second phenomena mentioned above, de-skilling. However, for this to happen these technologies would need to reach the point where no verification of the work they perform is required. This would mean that farmers could detach themselves from the field and focus on farm management. Nonetheless, the participant technology developers and researchers agree that this is not yet the case. On the contrary, ensuring that the equipment can check the quality of the work done on the field is the largest challenge yet to be tackled. For this reason, there is not a consensus regarding the de-skilling of the farmers. For Kreukniet (Trabotyx) this is just:

> "(…) arrogance from the technology sector. (…) The idea that you can understand the land better with some sensors than a person that has work it for 30 years, is complete [nonsense]. On the other side, you can get a lot of data and open their eyes and take little steps. That's possible. Taking little steps so that they can trust the technology and learn more from the land"

While the long-term effect of digital technologies on farmers' knowledge remains unknown, the cases presented show that up to now the effect is the opposite. The adoption of SC requires a wide range of adjustments in the farm operation and planning. As the current digital technologies still have to offer a solution that adjusts to this technique, farmers, developers, and researchers exchange their knowledge for the tinkering of new solutions. This does not only lead to the design of user-centered solutions, but to a re-skilling process of the participants as a result of this interaction. Moreover, these technologies have allowed farmers to become active participants in the debate over the impact of their activities. Van Boheemen (NPPL) shared how their increased access to data have allowed farmers to contest regulations that set standard caps for fertilizer use per area. Now, farmers can expose how some crops under certain circumstances might need to exceed these caps without incurring in over-fertilization. Hence, the crop estimations that come from research centers, the digital equipment, and farmers' knowledge overlap in this debate and allow for a greater participation of farmers on policy debates. Thus, technology not only shifts power to its developers as stated above, but allows an increased agency of farmers in the institutional arena.

As digital technology continues to pursue greater efficiencies, to reduce labour-stress, and increasing the information available for farmers, the latter continue to challenge these technologies on the field. Not only by testing them under diverse conditions, but by expanding the land imaginaries that shape the futures that are yet to be realized.

Chapter 5
Conclusions

The Dutch quest to achieve a sustainable intensification of its agricultural production is expanding its horizons through the search of biodiverse alternatives of growing food. Although so far the efforts were invested mainly on alternatives that rely heavily on increasing production while minimizing chemical inputs, SC is emerging as a possibility that includes this elements and goes beyond them. Precision agriculture has led to an increase of resource use efficiencies through data analysis, except it has mostly served to privilege an *intensification* of conventional agriculture over addressing the *sustainability* of it (Bos et al., 2013). Conversely, SC adopters in the Netherlands are building upon the benefits of precision agriculture while attempting to reconcile the negative correlation between yields and biodiversity. They are expanding the goal of agriculture beyond a simple maximization of productivity and profits to include sustainability. Though unevenly, they are transitioning towards an optimization of "a far more complex range of production, rural development, environmental, social and food consumption outcomes" (Bos et al., 2013: 71). However, while agricultural entrepreneurs have taken a leading role in this, questions regarding the governance of this shift arise. Although the existent institutional framework has already led to some progress on this respect, the transition towards a more biodiverse agriculture challenges the capacity of these institutions to adjust to the new practices and to incentivize their adoption. Governmental bodies, food industry and civil society need to address the need to opt for a pricing mechanism that includes the unobserved costs of cheap food, to encourage diets that foster production within the planetary boundaries, and to design the corresponding incentives for farmers to venture in the adoption of biodiverse agriculture, while correcting the current barriers for its success.

Nonetheless, SC has not been sufficiently researched for it to become the new standard for agricultural production. This becomes manifest in the uncertainty of the effects of certain crop rotations regardless of the efforts of highly skilled farmers and researchers, on the precision trap (Visser, Sippel and Thiemann, 2021) around the current offer of digital solutions, and their lack of fit to the conditions of SC. Still, it is important to highlight from this process of adoption how farmers, researchers and technology developers have interacted in a mutually reinforcing dynamic of knowledge production. A degree of alignment of the imaginaries of these actors allowed to reduce the frictions that arise from the process of adoption while shedding some light over an alternative future for agriculture. The operational complexity of SC not only has demanded the tinkering (Higgins et al. 2007) of the equipment used to fit with the new spatial conditions, but also an expanded understanding of the importance of biodiversity for farming. To overcome the environmental and economic constraints that affect agricultural entrepreneurs, the conception of soil as a technology opens a new world of possibilities that are also caring of the non-human. Thus, soil imaginaries and sociotechnical imaginaries feed each other in the process of development of solutions for SC. However, an additional level of alignment that should exist is with the consumers as coinciding imaginaries create greater interest to purchase produce with these characteristics. This is challenging due to the current detachment of consumers, but also of regulators, as they are not entirely conscious of the realities and restrictions that farmers face.

As discussed, imaginaries are political narrations of a society's particular sightedness and blindness and the trade-offs that inevitably accompany attempts to build a shared normative order (Jasanoff, 2015). While the sightedness could include the greater relevance given to biodiversity and the environment, it is equally important to address some of the blindness of these narrations. The first of two prominent ones is, how the increasing land concentration is only considered as a technical issue by making crop monitoring more difficult, while disregarding the effect that this has on small-scale producers. The second one is the effect that increasing automation might have on low-skilled workers. While at a domestic level this affects only a few workers that found in the fields a way of living, it is important to consider the potential these technologies have of becoming hegemonic and increasing land concentration while creating greater disruption in agricultural sectors that have been more labour intensive. Although this research has shown that the adoption of SC and digital technologies responds to contextual realities of Dutch agriculture, these potential effects should not be overseen.

"Indigenous communities with ancient practices know how plants work and in industrialization we completely forgot about all these things. But now, through all this data now we listen to people. And even though we can still not prove it, now we measure the effects, and we see that it works."
– Tim Kreukniet (Trabotyx)

Appendices

Appendix 1. COVID-19 Protocol on In-person Fieldwork Research by ISS MA Students

July 20/2021

Information to be Provided When Applying for In-person Fieldwork

- Describe the Covid-19 circumstances in the proposed place of research; and the measures / restrictions / health and other advice regarding Covid-19 in place in the proposed place of research.

During my fieldwork I plan to visit eight different farmers located in different cities in the south of the Netherlands. My research will imply participant observation of on-farm processes related with digital agriculture in an open space. This will later be complemented with interviews with each of the farmers and the technological partners involved in the process of co-development I aim to study. At all times I will comply with the rules of the government against Covid-19 regarding gatherings indoors, outdoors and travelling in the country. Now there are no restrictions regarding the number of visitors that a person can receive at their home/farm both indoors and outdoors. The recommendations to reduce risk in the encounters that will take place include maintaining 1.5 meters distance, making frequent use of disinfectant hand gel and handwashing facilities. As a complementary measure, I will take self-tests before each visit to make sure I might not be a carrier of the virus. Also, I will make use of masks when we are in reduced spaces where the recommended distance cannot be kept and/or ventilation is not favorable. During my transportation, I will avoid using public transport in peak hours to reduce the risk of infection.

The 'do-no harm' principle now also relates specifically to the possibility of COVID-19 infections, of the MA student, research assistants, research participants, and others. Describe the measures which will be taken to minimize the risk of COVID-19 infection during fieldwork.

- What measures will be taken to protect/minimize health risks to the health of the MA student, research assistants and participants, and those they will be in contact with afterwards?

Before meeting with the interviewees, I will communicate to them the importance for them and I to comply to the rules of the government against Covid-19. This, emphasizing the importance of hygienic measures and making sure that the spaces where we are planning to meet comply with the recommendations of the Dutch government. As a complement, I plan to bring antigenic self-tests with me to make sure I am negative before to go to the places I am going to conduct interviews. The importance of complying with these measures will be discussed as well upon my encounter with the research subjects.

Methodology:

My research consists of visiting farmers that are co-developing/implementing digital technologies for strip cultivation in the Netherlands. This means a sample of eight different farms which I plan to visit from August 11th to August 31st. On these visits I will get to know first-hand how the process of implementation of digital technologies takes place on-farm, and I will complement this with interviews to these farmers and the technological partners that are advising them on the process.

- Are the specific proposed protective measures available and affordable?

The hygienic measures I will comply with and that I will encourage strongly to the participants to comply to are not costly and widely available. This includes the frequent use of hand sanitizer, hand washing, antigenic self-tests, and use of masks when ventilation conditions are not favorable. Given that by August 11th I will be fully vaccinated, and that in the Netherlands over the 42% of the population is fully vaccinated as well, the risks of having complications from Covid-19 are reduced significantly. Still, I will keep a safe distance from the participants even when we are outdoors to reduce any risk of contagion.

- Considering the above, how was the research methodology adapted, for example so that social distancing and other preventive measures will be observed?

The research process will take place partly on the field while getting to know farmers' experiences with digital technologies. This is a scenario of low risk considering that it will be outdoors. When the interview takes place, the safety protocol will be followed strictly, specially regarding the distance and hygienic measures. This, after having tested negative for the antigenic self-tests prior to each encounter. In case a new interview is required, the possibility of an online call will be considered to reduce infection risks.

The 'do-no harm' principle now also relates specifically to preventing MA students, research assistants, and research participants from getting into situations where they cannot abide by local, Corona-related restrictions such as travel bans, quarantines, use of face masks, or curfews.

- If applicable, describe the measures taken to avoid 'doing harm'.
- Are specific protective measures necessary, and are they available and affordable?
- Any other relevant information.

Considering that I will have completed my vaccination protocol, that vaccination rates continue rising in the Netherlands, and that the setup of my research focuses mainly on on-field farm experiences, the risks of contagion are not particularly high. At every moment I will be complying with the corresponding rules, but also monitoring my own health in order to avoid spreading the disease. In case I turn out to be a carrier of the virus, I will refrain from continuing with my research process and look for online alternatives that allow me to fulfill my research objectives even if they need to be reformulated. I plan to ensure my own safety and that of the participants by stating clearly the importance of obeying these measures and complying with them.

- How to act in case of a new outbreak or upsurge of COVID-19 in the research location?
- Describe the measures taken to ensure that all involved in the research will stay up-to-date on the COVID-19-related risks and preventive measures to be taken.

As the researcher, I am going to complete my vaccination scheme fully before starting the encounters with the farmers. I will be up to date to new rules that apply for gatherings and hygienic measurements in the Netherlands. Taking into account that I will not leave the country, this means that transportation in case of any emergency is not very complicated and will be covered by the AON medical insurance acquired as student of ISS. With regards to the participants, I will state clearly the objective of the research, and the rules that should be followed in order to minimize any risk of contagion. I will validate with the farmers their state of vaccination if they want to disclose it in order to take additional measures if necessary and if they accept the meet up.

- How will the MA student act in case of a drastic change in the local COVID-19 situation:

I would pause the in-person field research and return to the Hague and finish my research online.

Appendix 2. NPPL participants with Strip Cultivation

Interviewee	Location	Area	Starting date SF	Strip Width	Objective of the Farm	Overall aim	Possible crops	Background info
Theo Nieuwenhuis	Didam (Gld.)	50 ha in total, 16 ha for strip cultivation	2021	ND	Organic field vegetables with minimal tillage.	To improve biodiversity above and below ground and to increase the carbon content in the soil.	White cabbage, red cabbage, fodder beet, sweet corn, sunflower seeds, green beans.	Dairy farmer until 2018. Soil consultant that guides dairy farmers who opt for circular agriculture. His company is called Edaphon.
Remco Wesdorp	Sommelsdijk (Z.-H.)	100 ha + 70 ha for SC [Leased with Huibert Groeneveld]	2021	20-40 m	Potatoes, onions, grains, flower bulbs, beets.	Staying competitive under increasing regulation on chemical products and environmental factors. Closing cycles and increasing biodiversity.	Potatoes, onions, maize, grass-clover, field beans, fodder beets, alfalfa, soy, sorghum.	Arable farmer Remco Wesdorp, cattle farmer Huibert Groeneveld and business economics student Martijn Groenendijk will work on 70 hectares of SC in the Van Pallandtpolder Experimental Garden.
Huibert Groeneveld	Sommelsdijk (Z.-H.)	85 ha for cattle and 70 ha for SC [Leased along Remco Wesdorp]	2021	20-40 m	Dairy farm with 150 cows.			
Jacob van den Borne	Reusel (N.-Br.)	600 ha – 180 plots of approximately 3 ha. [Not only for SC]	2019	3 m	Potato (Zorba, Lady Anna, Fontana, Ivory Russet varieties), sugar beet and maize crops.	Working on variable aspersion based on crop, soil and technology parameters, increased automation, SC and fertilizer-free soil im-provement.	ND	Started working with precision farming since 2006. Third-generation farmer. Stands by the reduced use of chemical inputs for pest control and herbicides. He has a training and experimental institute where he works with drones for agriculture.
Cornelis Mosselman	Goere-Overflakkee (Z.-H.)	50 ha in total. For SC 15 ha in 2020 and 36 ha in 2021.	2020	3.2 m	Organic production of eight crops.	Implement a market oriented sustainable agriculture.	ND	Changed to organic production in 2018. Works with permanent tramlines. Six-generation farmer.

Source: Author based on publicly available information from the NPPL website and others.

Appendix 3. Definition of 'good farming' by a selection of interviewees

Name	Project	Good farming	Most important factor in farming
Leandro Barberi	Soil Heroes	"It is about the efficient use of resources, taking care of the ecosystem, having sustainable profits on the long term, producing good quality food, diverse, regenerative, building up the quality of the soil, and having a good experience working there."	"While soil is more important that data, it is on the latter that we base our decisions. We have been on agriculture for thousands of years but data only for the last 500."
Koen van Boheemen	NPPL	"Producing a product that is healthy for the consumer. You want this product to be free of any diseases, bugs and pests. You also want to make sure that chemicals are used as little as possible in the production of this product."	"I would say skilled labor. The farmer, the one that is putting it all together. Because there can be high quality seeds, high quality fertilizers, high quality soil, but if there's nobody who knows how to put them all to use, then you have nothing."
Arend Koekoek	Pixelfarming Robotics	"It means that everybody has access to healthy food, from a healthy soil in a comfortable environment where people can live. It's all about food for people, that's my goal. Food for everybody as cheap as possible, or that everybody can afford it."	"Currently, technology to reduce labor stress. What we see is that it is possible to make food while promoting biodiversity, but it requires an enormous amount of human labor to get this beautiful healthy food. And all this labor can be replaced by technology."
Tim Kreukniet	Trabotyx	"It's not something I should answer. I am not a farmer. But I would hope, farming within the planetary boundaries and running a proper business unsubsidized."	"The openness to change. The willingness to look into the future from a planet perspective. Then, the business side will change completely."

(Author, 2021

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