Feeding the world with an app : Digital agriculture, startups, and the appeal of little devices

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CCD	Colony Collapse Disorder
CGIAR	Consultative Group for International Agricultural Research
CSREES	Cooperative State Research, Education, and Extension Service
DAU	Daily Active Users
FAO	Food and Agriculture Organization
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IPM	Integrated Pest Management
KPI	Key Performance Indicator
Ld50	Median Lethal Dose
MAU	Monthly Active Users
PHI	Preharvest Interval
PPP	Public-Private Partnership
RAD	Rapid Application Development
SMS	Short Message Service
SQL	Structured Query Language
UX	User Experience
WAU	Weekly Active Users
WHO	World Health Organization
WTO	World Trade Organization

General introduction: Feeding the world with an app

Prologue: "Software will eat the world – PHYTØ will feed the world"

Wanda[1] stands on a stage illuminated in blue. It is fall 2019 and the CEO of the young agtech[2] startup FLORA[3] is presenting her project at a popular European entrepreneurial conference. Behind her, a projector casts her opening slide on the wall; an aerial view of a field half mowed down by a combine harvester. The slide says: "Mankind's biggest challenge: Food production." A man in the front row wearing a black suit and white collar raises his smartphone to snap a photo of the scenery.[4] After the welcoming applause has ebbed away, Wanda begins—in tune with the slide—to describe the problem her startup seeks to solve.

> "Thank you, absolutely happy to be here. I would like to talk about mankind's biggest challenge for the next decade. Actually, in my opinion this is not Brexit, this is not Donald Trump, but this is global food production. I mean this is only logical, if we think that our population is rising, and that we will be 10 billion people by 2050. At the same time, we also need to produce 70 percent more food by 2050—in particular in regions like Africa or Asia. But the question is: How are we going to achieve this?"

This opening statement instantly makes clear that Wanda's startup is not concerned with trivialities, but with nothing less than saving the world from starvation. It lends moral gravitas to the work of her startup and piques curiosity, mine at least, to learn more about the innovation it has to offer. "Yes," one may wonder, "how are they actually going to achieve this?" Not leaving this question unanswered, Wanda continues:

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[1] This name and all other names of people who are connected with the startup examined in this dissertation are pseudonyms.

[2] The boundaries of the term agtech are fluid and not always clearly delineable. As an example, a vernacular definition of the term states that "AgTech is the use of technology in agriculture, horticulture, and aquaculture with the aim of improving yield, efficiency and profitability for farm managers and growers." Source: Bitwise Industries. (2022, August 15). *What is agtech and why is it important?* https://bitwiseindustries.com/blogs/category-blog-agtech/

[3] The name of the startup, the names of all its apps, and the names of certain features of those apps studied in this thesis are pseudonyms.

[4] I was not at the conference myself. The observations are taken from a video recording made by the conference organizers.

> "At FLORA we believe that we can only achieve this if we support small-scale farmers, and we talk about a lot of small-scale farmers. We talk about more than 500 million farms out there. And this is actually also the next billion who will get access to internet via smartphones. So, that's why we created PHYTØ, a smartphone application to support small-scale farmers, and already today we are the biggest agricultural app worldwide."

The message is clear: Food security can only be achieved by supporting the large number of small-scale farmers around the world. The talk is of "millions," no "billions," of these small-scale farmers, and by all appearances Wanda's startup has developed a technology that can actually reach this unimaginably large group of people, "the biggest agriculture app worldwide." Of course, these numbers must be taken with a grain of salt, as agtech pitches should always be seen as performative devices aimed at convincing investors that a given technology is a worthwhile investment (Fairbairn et al., 2022). Through this lens, the mobilized numbers can be understood not only as numbers, but as a demonstration of "scalability" (Pfotenhauer et al., 2021). Apart from these theoretical reflections, one (a reader, an investor, a fellow entrepreneur, etc.) may also wonder, simply, how exactly does PHYTØ support small-scale farmers. Wanda provides the following answer:

> "Imagine, how cool would it be? You take a smartphone, you snap an image, and within seconds you know what's your problem, and how you can treat it. That's actually what we do with PHYTØ. We use AI, machine learning, image recognition to train algorithms, to identify plant damages.[5] We can already identify 500 different damages on 50 crops, and millions of users are using this core feature of PHYTØ, to identify their problems. So, we get more than thirty thousand pictures every day from our users, which helps us to create the biggest database worldwide with more than 15 million pictures."

This quote relatively succinctly summarizes the technological core of PHYTØ and how FLORA intends to use it to help achieve global food security. As revealed to the audience of Wanda's pitch, PHYTØ is a mobile app that uses a set of image processing algorithms to detect plant damages on images uploaded by users, and then tells those users how to treat these plant damages. Once again, the audience is presented with figures. This time, the figures testify to the technological progress of PHYTØ ("500 different damages," "50 crops") and the popularity of the app among users ("millions of users," "more than 15 million pictures"). "Fair and good,"

[5] Congruent with the FLORA team in many situations, this thesis uses the term "plant damage" as an umbrella term for the totality of symptoms caused by plant pests, diseases, and nutrient deficiencies.

a savvy investor might wonder, "but how can this technology be monetized?". For this question too Wanda has an answer up her sleeve:

> "So, we already support farmers, millions of farmers to increase their productivity. […] In the next step and to get our feet on the ground, we integrate the retailer in our ecosystem. You can imagine like an online-doctor-pharmacy-relationship between them. So, we advise the farmer. We give them a solution, and a prescription. With this prescription we send him to his local retailer to make sure that he really gets the right product. We exchange data with both the farmer and the retailer, but the goods are still going the old way, from the retailer to the farmer. But if we extend our data exchange also to the input providers, to the input producers, then we make the whole value chain transparent, and we can help to make it more effective. That's what we call a smart agri-ecosystem in the end. I mean we make definitely sure that the products are steered to us. This not only makes farmers and retailers happy, but also our investors, again."

As the pitch draws to a close, FLORA's CEO thus eventually explains her startup's business model to the audience. The way Wanda describes it, FLORA aims to extract revenue from its broad user base by acting as a wholesaler for pesticides and other inputs. To that end, her startup was currently in the process of integrating retailers into its "ecosystem," by which Wanda means two things: First, developing a new app for that user group, and second, establishing business relations with "input providers," that is, agrochemical corporations, to subsequently charge commissions on additional sales that FLORA would broker to them. After outlining this business model, Wanda presents a few more slides with numbers and charts showing that FLORA has already made notable progress in attracting pesticide retailers as a new user group and in making contacts with pesticide manufacturers, before concluding the pitch with her startup's memorable slogan:

> "So let me finish, with the next slide, some of you may know the quote: Software will eat the world—with your support, we say—PHYTØ will feed the world. Thank you very much."

Problem

The previously recounted pitch is by no means the only occasion on which the agriculture app PHYTØ is staged as a digital solution to the problem of food security. The startup regularly reproduces this claim in a similar manner in podcasts, on social media, or in self-produced YouTube videos. At the same time, third parties are jumping on the bandwagon. As an example, one can find business partners of PHYTØ proclaiming things like "together we ensure a safe food production for us and the generations to come!", politicians posing with PHYTØ in front of cameras to emphasize their concern with agriculture and food production, and journalists claiming that FLORA "has set out to do nothing less than to help feed the hunger of the world."

To cut to the chase, all of these more or less grandiose assertions beg a central question: How exactly does PHYTØ feed the world? This is the question at the heart of this dissertation. More formally put, by combining an STS-informed approach to digital agriculture (e.g., Bronson, 2019; Bronson & Knezevic, 2016) with an STS-informed understanding of food security as a highly malleable and therefore controversial concept (De Raymond & Goulet, 2020) the dissertation asks how the problem of food security is addressed by the agtech startup FLORA throughout the development process of the agriculture app PHYTØ. Specifically, this means that the dissertation does not attempt to judge once and for all whether or not PHYTØ achieves a predefined notion of food security, but rather is interested in tracing the interpretations of food security that emerge within FLORA during the app's development process. The theoretical motive that underlies this question can be broken down to the intent of taking PHYTØ and the claim that it can "feed the world" seriously, as a "matter of concern" (Latour, 2004). In practice, this means that the dissertation strives to neither naively celebrate nor critically reject the statement prematurely, but to trace it empirically by trying to pinpoint what "feeding the world" means for the actors involved in the case of PHYTØ.

This primary research question is supported by two accompanying sub-questions. The first of these sub-questions situates the dissertation—in addition to its situatedness in debates about digital agriculture and food security—in debates about the growing influence of agtech and foodtech[6] startups in contemporary agrifood systems (e.g., Fairbairn & Guthman, 2020) and in debates about startups as spaces of knowledge production (e.g., Fochler, 2016) and reads as follows: How does the agtech startup FLORA transform food security into a problem that can be solved by means of digital technology, and how does the team of the startup produce agriculturally relevant knowledge in this process?

The second sub-question aims to bridge recent debates on the proliferation of "little development devices" (Collier et al., 2017), as a response to ongoing criticisms targeted at

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[6] As with the term "agtech," it is not my intention to define the term "foodtech" conclusively. However, to provide a broad idea of its meaning, an illustrative vernacular definition reads as follows: "Foodtech or food technology is the usage of cutting-edge technologies to develop, manufacture, and distribute food products." Source: Feedough. (2022, August 24). *What is foodtech?: Use cases, examples, & futures.* https://www.feedough.com/what-is-foodtech/

large-scale modernization projects of the past (in the field of development), and the proliferation of small, often digital, devices in agriculture such as soil sensors, GPS cattle trackers, drones, or apps. More specifically, the dissertation hypothesizes that the proliferation of little devices in agriculture—”little agriculture devices,” so to speak—should be seen as a response to ongoing controversies regarding large-scale agricultural modernization projects of the past, most notably the green revolution, with its large-scale research infrastructures for breeding new high-yielding varieties in various climates (Fitzgerald, 1986), to cite just one example. To test this preliminary hypothesis the dissertation thus asks: How exactly does the little agriculture device PHYTØ respond to agriculture-related controversies of the past?

The methodology for this analytical endeavor consists of a combination of “multi-sited ethnography” (Marcus, 1995) and “multi-situated app studies” (Dieter et al., 2019), meaning that PHYTØ is followed across different geographic locations and through different infrastructural settings (e.g., interfaces). Through this methodological approach, the dissertation formulates four arguments in response to the above-mentioned questions, four arguments that revolve around four problems that have emerged in FLORA’s efforts to break down the complex problem of food insecurity into a series of smaller problems that can be solved by means of an agriculture app. As will become clear, these arguments apply not only to the case of PHYTØ but help to understand more generally how agtech startups developing little digital agriculture technologies are addressing “grand challenges” (Kaldewey, 2018) including but not limited to food security. These four arguments are that the respective startups (1) are engaged in a process of exploratively assetizing agtech, (2) selectively recognizing agricultural phenomena, (3) collectively enacting expertise, and (4) coherently representing users.

Having clarified these basic elements, the rest of this introduction is structured as follows: The first section is a literature review in which the questions outlined above are derived in more detail from the corresponding strands of research. In section two, the agtech startup FLORA and the agriculture app PHYTØ, that is, the case in focus of this thesis, are presented in more detail. Section three explains the methodology, research design, and methods used to examine this case. Lastly, section four provides an outline of the four empirical chapters of this dissertation and a more fine-grained summary of the four arguments they develop.

The conflation of digital agriculture and food security

FLORA is far from being the only actor claiming that digital agriculture technologies can make an important contribution to achieving the goal of food security. To give another example, in a 2021 episode of its podcast series "Table for 10 Billion," the World Bank posed the question "Is Digital Agriculture Key to Food Security?".[7] The podcast largely answered this question in the affirmative, arguing that digital agriculture can play a key role in achieving the second UN Sustainable Development Goal, "Zero Hunger by 2030." This subsection complicates the answer to this question by performing a two-part move: On the one hand, it shows that both digital agriculture and food security are relatively contested objects in their own right, which makes it difficult to say once and for all whether one leads to the other. On the other hand, it shows that in the analyses of critical social science and humanities scholars studying these two phenomena, an overlap emerges with respect to the documented consequences of them for agrifood systems. This overlap lies in the fact that both groups of researchers describe how the respective phenomena, depending on their manifestation, can perpetuate, rather than break with, forms of exploitative or productivist agriculture that might pose a threat to food security, depending on how one interprets the term. Building on this, the subsection closes with a theoretical outlook on how this contentious conflation between digital agriculture and food security can be explored empirically.

For the start, an illustrative—because relatively common—definition of digital agriculture[8] comes from the Agricultural Experiment Station at Cornell University, which describes it as a

[7] Fields, J. (2021, May 26). *Table for 10 billion podcast: Is digital agriculture key to food security?* The World Bank Group. https://www.worldbank.org/en/news/podcast/2021/05/24/podcasts-is-digital-agriculture-the-key-to-food-security

[8] Semantically, it is difficult to clearly delineate digital agriculture as there are many coexisting definitions, synonyms, and closely related terms which more or less interchangeably describe the increasing use of digital technologies in agriculture. Other terms circulating in the public sphere include "smart agriculture," which associates the phenomenon with related trends such as "smart medicine" and "smart cities," or "Agriculture 4.0," which conveys a somewhat stronger "web 4.0" feel. Moreover, some specialists describe digital agriculture as an evolution of "precision agriculture." On the one hand, this is because the notion of precision agriculture is older, dating back to the first introduction of GPS technologies to agriculture in the late 1980s. On the other hand, it is because the term precision agriculture—strictly speaking—only applies to pre-harvest operations. However, in practice many actors use the terms digital agriculture and precision agriculture interchangeably. With this in mind,

state of agricultural systems in which "[d]igital technologies and analytics are used to optimize key components of food systems, increasing productivity and profitability, while reducing environmental impacts."[9] The "common" element of this definition is above all its emphasis on digital agriculture as a matter of simultaneously increasing productivity and decreasing environmental damage.

This promise of simultaneously increasing productivity and saving the environment has also led many governments around the world to actively promote digital agriculture in their policies. For instance, in 2019 the European Commission announced that "EU Member States join forces on digitalisation for European agriculture and rural areas."[10] Similarly, in 2020 China's Central Cyberspace Affairs Commission together with the Ministry of Agriculture and Rural Affairs published plans to "to accelerate development of precision agriculture and rural production and administration."[11] As a last example—and of particular importance to this dissertation—in 2021 the Indian government launched its "Digital Agriculture Mission 2021-2025" to "build innovative agri-focused solutions leveraging digital technologies to contribute effectively towards increasing the income of farmers and improving efficiency of the Agriculture sector in the country."[12]

This broad endorsement of digital agriculture is also prevalent when looking at the reactions that the phenomenon has sparked in the natural, engineering, and life sciences. Starting approximately around the year 2000, a growing body of research concerning digital agriculture can be identified across these disciplinary clusters that sheds a very promising light on digital agriculture. The majority of the respective publications is specialized in specific technologies

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this dissertation uses the term digital agriculture, not because of semantic subtleties, but because it is the term that the actors of FLORA most often use to describe their efforts.

[9] Cornell University Agricultural Experiment Station. (2022, August 24). *Digital agriculture.* CornellCALS. https://cuaes.cals.cornell.edu/digital-agriculture/

[10] European Commission. (2019, April 9). *EU member states join forces on digitalisation for European agriculture and rural areas.* https://digital-strategy.ec.europa.eu/en/news/eu-member-states-join-forces-digitalisation-european-agriculture-and-rural-areas

[11] Xinhuanet. (2020, January 20). *China issues plan for digital agricultural, rural development.* http://www.xinhuanet.com/english/2020-01/20/c_138720773.htm

[12] Ministry of Agriculture & Farmers Welfare. (2022, April 5). *Digital agriculture mission.* https://pib.gov.in/PressReleasePage.aspx?PRID=1813681

associated with digital agriculture. For instance, review articles can be found that focus on agricultural robotics (e.g., Ramin Shamshiri et al., 2018), artificial intelligence (e.g., Smith, 2020), the internet of things (e.g., Verdouw et al., 2013), 3D food printing (e.g., Voon et al., 2019), computer vision (e.g., Patrício & Rieder, 2018), drones (Mogili & Deepak, 2018), remote sensing (e.g., Hunt & Daughtry, 2018), ICT (e.g., El Bilali & Allahyari, 2018) or big data (e.g., Kamilaris et al., 2017). Consistent with the definition from the Agricultural Experiment Station at Cornell University cited above, a general argument running through all of these review articles is that the respective digital agriculture technologies can be expected to increase the productivity of agriculture and at the same time decrease the environmental damage it causes—an argument that is also very popular among economists concerned with digital agriculture (Basso & Antle, 2020).

As a contrast, recent decades have seen the emergence of a steadily growing number of publications in the social sciences and humanities that are more skeptical of digital agriculture and its enticing promise of increasing productivity while reducing environmental degradation. This strand of research is one of the core bodies of literature from which this dissertation draws inspiration and to which it hopes to contribute. Given this, the respective studies and the sub-strands they form will be discussed in detail over the course of the individual chapters. At this point, it shall suffice to outline one of these sub-strands, in order to illustrate how its perspective on digital agriculture differs from the perspectives on digital agriculture described above.

A key debate among social science and humanities scholars studying digital agriculture interrogates the ways in which companies that provide digital agricultural technologies generate, analyze, and capitalize on agriculturally relevant data, sometimes referred to as “big data.” One of the first publications on this question came from Bronson and Knezevic (2016) who drew together theoretical insights from the fields of critical data studies and critical food studies to examine the growing importance of big data in food and agriculture. In order to investigate this question, the authors reviewed different big data-driven digital agriculture technologies, such as Monsanto’s “Weed I.D.” app, and made the now widely accepted argument that “Big Data is poised to reproduce long-standing relationships between food system players” (p. 3), such as the unequal power relationship between farmers and input companies, or between farmers and large food producing companies. Likewise focusing on Monsanto’s forays into digital agriculture, Carbonell (2016) makes a similar argument stressing that “[b]ig data and analytics on conventional industrial farms […] focus almost exclusively on inputs and production” while neglecting, for example, “industrial agriculture externalities and vulnerabilities" (p. 3)—an effect that she summarizes as the "selective use of big data in agriculture" (ibid.). Fraser (2019) extends these observations of a data-driven exacerbation of historical inequalities in agriculture to farmers in countries of the Global South. More specifically, he argues that the proliferation of digital agriculture technologies in countries of the Global South, which is often portrayed by its proponents as an equitable "exchange" (e.g., user data in exchange for enhanced digital analytics services), should be viewed more as an opportunistic "data grab" in which farmers are dispossessed of their data, to the unilateral benefit of companies or investors from Global North countries. Fraser's analysis also resonates with Fairbairn and Kish (2021) who argue that farmers in countries of the Global South are often said to suffer from an alleged "data deficit." This data deficit, they go on to argue, provides a strong rational for blanketing these farmers with digital technologies, while distracting from the problems that led to their increased vulnerability in the first place (e.g., colonialism, capitalism, neoliberalism).

This list of studies could easily be expanded, but for now it will suffice to point out that social science and humanities scholars who study digital agriculture, while not a priori opposed to the phenomenon, alert us to the reality that digital agriculture cannot be reduced to the simple formula of increasing production and reducing environmental damage. Rather, as the above-cited studies indicate, in some cases digital agriculture can even have the opposite effect jeopardizing the well-being of the environment, farmers, or broader society. This Janus-faced nature of digital agriculture—to summarize one fundamental insight that this dissertation draws from the studies cited above—requires ongoing empirical engagement with the technologies it gives rise to and the kinds of agriculture and food production they foster.

To better understand the intertwining of digital agriculture and food security, it is equally necessary to take a closer look at the object of the latter and what makes it controversial. A definition of food security that is still widely used today was put forward at the FAO World Food Summit in 1996. According to said definition food security is achieved "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life."[13] While early debates about food security faded over time, they gained new momentum with the 2008 food price

[13] World Food Summit. (1996, November 13-17). *Rome Declaration on World Food Security.* https://www.fao.org/3/w3613e/w3613e00.htm

crisis (Duncan, 2015), in the sense that food security again became a stronger priority of international organizations and research institutions. This tendency was also accompanied by a growing trend among scientists, policy makers, and representatives of international organizations to argue in terms of "feeding the world in 2050" (Goulet, 2012), with a vaguely grounded consensus emerging that global food production would need to increase by 70 to 100 percent by that year—a vaguely grounded consensus that quickly expanded into a political imperative.

Since the early 2000s, this imperative and the associated interpretation of food security have been increasingly criticized by scholars from various disciplines. A seminal analysis in this regard was provided by the geographer Tomlinson (2013), who examined recent discourses on food security and the purported need to increase by 70 to 100 percent by 2050, focusing on the United Kingdom. As Tomlinson argues, the statistics on which said imperative is based do not withstand closer scrutinization. Surprisingly, she continues, the statistics have nevertheless come to dominate public debates about food security in the United Kingdom and beyond. The explanation she mentions for this is that they have become "a key discursive device used by dominant institutions and individuals with prior ideological commitments to a particular framing of the food security issue" (p. 81). By this "particular framing," Tomlinson refers to a framing of food security that is centered on production and that "does not address problems of climate change, diet-related ill health and does not substantially reduce absolute levels of hunger" (p. 88). Simply put, she criticizes that the imperative embodied by the questionable statistics reduces the complex problem of achieving food security to a mere problem of increasing production. Based on this argument, Tomlinson concludes that the notion of "food security" as it is predominantly used today is likely to "exacerbate many of the existing problems with the current global food system" (p. 82).

Tomlinson is not alone in this assessment. Even more direct in tone, Fouilleux et al. (2017), in an analysis of documents published by international organizations (e.g., FAO, WFP, OECD), NGOs (e.g., Oxfam, IATP), and public administrations argue that most debates concerned with food security exhibit a "productionist bias" (p. 1). To clarify, they define productionism as "the tendency to reduce the complex food security issue to a need to increase production" (p. 5). Hence, very similar to Tomlinson (2013), the authors stress that contemporary efforts to attain food security reflect a narrowing of the notion's potential range of meanings. More specifically, they argue that the interpretation of food security as merely an increase in production that is maintained by a few powerful institutions suppresses the meanings that the term has for other, less powerful actors—meanings associated with issues like "poverty, unemployment, prices, gender aspects, consumption patterns, [or] nutrition" (p. 15).

Against the background of these debates, the question arises as to how the contested object of digital agriculture and the contested object of food security can be studied in conjunction. In an introduction to a special issue on "Science, Technology and Food Security" De Raymond and Goulet (2020) outline an approach that lends itself for this analytical synthesis. More specifically, they suggest to combine insights from critical analyses of food security with the theoretical and methodological sensitivities of STS in order to move the analysis of contemporary manifestations of the pursuit of food security beyond the mere exposure of productionism. To this end, they articulate a number of questions that inform the contributions to the special issue, such as: "How has this grand food security challenge actually been approached by scientific and technological organisations, be they public or private?" (p. 2), "What knowledge tools or infrastructures have been developed and how have they helped to shape debates on food security?" (ibid.), or "More broadly, in what ways does the case of food security help to throw light on contemporary changes in research and farming technologies and on their place within national or international agendas?" (ibid.). The common denominator of these questions—their STS influence if you will—is that they do not seek to reveal a 'true' meaning of food security and make a final judgment on whether a particular innovation corresponds to that meaning, but rather take the notion as a vehicle to interrogate contemporary developments in the agricultural sector including the emergence of new technologies.

With its main question, "How exactly does PHYTØ feed the world?", the dissertation follows the approach sketched by De Raymond and Goulet by examining in depth one technology that was created in the name of this renewed interest in food security. In this sense, my research is not intended to conclusively assess whether or not PHYTØ is achieving its goal of contributing to food security. Rather, it views the app as a window to observe and describe contemporary efforts to feed the world with technological means, in order to understand what they can tell us about the current state of agriculture.

Agtech startups, solutionism, and knowledge

One group of organizations that is among the most active in developing and disseminating digital technologies in the name of food security are agtech startups. As the Venture Capital Journal just recently brought it to the point, "[a]gtech is booming, fueled by worries about food security."[14] Food security is far from the only "grand challenge" (Kaldewey, 2018) that agtech startups have begun to embrace. Similarly, numerous agtech startups can be found claiming to tackle climate change, biodiversity loss, pollution, or combinations of all of the above. In recent years, however, a small but growing group of STS-informed sociologists, anthropologists, and geographers have begun to challenge these claims and to examine more generally how the startups that express them are changing agrifood systems. These studies represent another important body of literature that theoretically informs the problem of this dissertation.

STS-informed research on agtech startups is a fairly recent development spearheaded by, but not limited to, a group of researchers affiliated with the University of California studying agtech and foodtech startups in Silicon Valley, known as the Agri-Food Technology Research (AFTeR) Project.[15] According to a self-description on the project's website, the research group "explores the emerging Silicon Valley-based Food Tech and Ag Tech sectors […], seeking to understand the transformative potential of novel agrifood tech products and the visions that underpin them." One of the key questions they grapple with in this endeavor, the website continues, is "How sector actors define problems and vet solutions in the context of the enormous and intersecting challenges of food security, climate change, ecological sustainability, and human health and well-being?".

In response to this question, Fairbairn and Guthman (2020), for example, have scrutinized the reactions of agtech and foodtech startups to the Covid-19 pandemic. To put it in their words, "[a]s the virus has carved its exponential path through our economic and social lives, the agri-food tech sector has undertaken an almost instantaneous repositioning" (p. 587). By this, the authors mean that Silicon Valley's agtech and foodtech startups were quick to frame the pandemic as a business opportunity and adapt their technologies accordingly. An example that they cite for this is that "[a] heightened awareness of animal-borne disease is providing new rationales for cellular meat and other alternative protein products that replace the need for livestock production" (ibid.). Yet other examples they mention are that "[c]ompanies involved in indoor vertical agriculture are amplifying claims about the superiority of their highly

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[14] Smith, C. C. (2022, July 8). *Agtech is booming, fueled by worries about food security.* Venture Capital Journal. https://www.venturecapitaljournal.com/agtech-is-booming-fueled-by-worries-about-food-security/

[15] UC AFTeR Project. (2022, September 3). The UC AFTeR Project: A California agri-food technology research collaboration. https://afterproject.sites.ucsc.edu/#research

controlled environments" (ibid.) and that an increased "concern about hand-to-face transmission of covid-19 is giving new justifications for the touchless harvest and food delivery promised by robotics" (ibid.). On the flip side, the authors continue, the startups in question usually neglect other problems caused by the pandemic, typically those affecting already marginalized groups within agrifood systems (e.g., minority farm and food service workers). Based on these observations, the authors argue that the described response of the startups to the pandemic is an expression of what they call "ag-tech solutionism," a notion that is inspired by the concept of "technological solutionism" which was coined by internet critic and historian of science Morozov (2013).

As Morozov defines it, technological solutionism refers to an ideology that recasts "all complex social situations [e.g., politics, public health, education, and law enforcement] either as neatly defined problems with definite, computable solutions or as transparent and self-evident processes that can be easily optimized" (p. 5). Simply put, technological solutionism refers to acts of reducing complex problems to rather simplistic problem definitions that are predetermined by the powerful yet limited tools available to technology companies. Against the background of this thought, Morozov further specifies his conceptualization stating that "[s]olutionism, thus is not just a fancy way of saying that for someone with a hammer, everything looks like a nail […] [but] also that what many solutionists presume to be 'problems' in need of solving are not problems at all" (p. 6). In other words, Morozov goes even one step further and argues that the companies in question—due to their technologically predetermined way of identifying problems—often choose the wrong problems to work on: "problems" that are "not problems at all."

Another important study from the same collective that adapts Morozov's concept to examine the response of Silicon Valley-based agtech and foodtech startups to the Covid-19 pandemic comes from Reisman (2021). As Reisman argues, the reaction of the respective startups to the pandemic ought to be interpreted as an expression of "disaster solutionism," which she defines as an amalgamation of neoliberalism and technological solutionism. As she puts it, "[m]uch as neoliberal ideology assumes social dilemmas can be remedied by market optimization, solutionism assumes they can be remedied by technological optimization" (p. 913), specifying that "[t]he combination of the two, what one might call disaster solutionism, has been a prevalent (though by no means exclusive) response to the COVID19 pandemic" (ibid.). What is particularly important about Reisman's argument is that it underscores how agtech and foodtech startups are taking advantage of the Covid-19 pandemic not only to open up new markets, but more importantly, to generate legitimacy for their technologies and to portray them as indispensable parts of society. This, Reisman concludes, often leads to an inadequate scrutiny of the long-term political or environmental effects of technologies developed by agtech and foodtech startups: "The disaster solutionist response to portray emerging technologies as inevitable risks a sanitizing effect, making critical considerations of their long-term political or ecological stakes appear irrelevant or even irresponsible" (pp. 927-928).

Aside from this focus on Covid-19, Guthman et al. (2022) have provided an insightful analyses of the efforts of Silicon Valley based startups and other private companies to produce and market so-called "alternative protein." As they explain the label of alternative protein covers a wide range of products that attract increasingly large amounts of venture capital such as meat substitutes made from plants (e.g., peas, soy, or kidney beans), lab-grown in vitro meat, or foodstuffs made from protein originating from insects. Against this backdrop, the authors' main argument regarding this trend is that the ostensible solutions these companies are developing in the name of global protein shortages distract from more structural social and environmental problems of conventional livestock production—problems in which the respective companies are often involved themselves (e.g., large food manufacturers that produce both conventional meat and alternative protein products).

With a partly different theoretical underpinning Fairbairn et al. (2022) analyze the entrepreneurial "pitch" as a device that can help to better understand the foray of agtech and foodtech startups into agrifood systems. Specifically, their study is based on ethnographic observations at 34 events where representatives of Silicon Valley-based agtech and foodtech startups presented their innovations to other startups and, more importantly, to potential investors. Based on this, the study develops a two-part argument. First, aligning themselves with a strand of economic sociology concerned with the performativity of market devices (Doganova & Eyquem-Renault, 2009; Doganova & Muniesa, 2015), the authors argue that the "agri-food tech pitch" is a device that allows entrepreneurs to handle a tension between "on the one hand, the combination of world-changing ambition and profit-making potential demanded by Silicon Valley investors and, on the other, the political economic realities of food and agriculture" (p. 3). By this they mean, very similar to the studies cited above, that the pitches in question offer the presenting entrepreneurs a performative space in which they can portray the historically grown, complex, and entrenched problems of agrifood systems as being solvable with the technologies developed by their startups, inevitably simplifying those problems in the course of their performance. The main purpose of navigating this tension, the authors continue to argue, is to dispel the doubts of potential investors and thus ensure the financial survival of the start-ups in question. As they phrase it, the agri-food tech pitch "must mediate between Silicon Valley investor desire to generate both profit and impact, and the entrenched political economic realities of food and agriculture" (p. 15). The second argument the authors make, borrowing a concept coined by Goldstein (2018), is that the pitches they studied indicate a tendency of the corresponding startups, but also of Silicon Valley at large, toward "non-disruptive disruption." Fairbairn et al. (2022) specify this concept by stating that "though couched in a discourse of revolutionary and systemic change, the sector primarily offers incremental improvements on existing technologies, often developed or marketed in partnership with industry incumbents" (p. 4).

I largely concur with all of these critiques of the burgeoning agtech and foodtech sectors, and the analysis that the respective startups rarely fully deliver on the promises they make in the course of persuading investors. However, in this dissertation I intend to look beyond the critiques of "technological solutionism" (Morozov, 2013) or "non-disruptive disruption" (Goldstein, 2018). To put it naively, one might say that the dissertation asks the following question: Assuming that agtech startups are not "solving" or "disrupting," what are they doing instead?

To grapple with this question, the dissertation draws inspiration from another STS-informed strand of sociological and anthropological scholarship that explores high-tech startups as novel (as compared to classic laboratories) spaces of knowledge production. An illustrative example of a study from this strand of research is a study by Fochler (2016) concerned with biotechnology startups in Europe. Fochler frames the problem of his study as follows:

> "[T]he rise of academic entrepreneurship and the outsourcing of corporate research have resulted in the emergence of a new institutional form in which knowledge is produced, tested and commercialized: the high-tech startup. These companies, often small and organizationally flexible, offer researchers new possibilities to live and work in research, beyond and between academia and larger industry. High-tech startup companies should be interesting research subjects from the perspective of science and technology studies (STS). They may be expected to house new cultures of knowledge production whose relation to the values and logics of academia and business is not clear a priori. Nevertheless, […] academics in STS have not shown a broad interest in understanding these new institutions and their cultures of knowledge production." (Fochler, 2016, p. 260)

As exceptions to this rule, he mentions for example studies by Rabinow (1997), Smith-Doerr (2005), or Shapin (2010). Given the relatively widespread neglect of high-tech startups as spaces of knowledge production within STS, aside from the aforementioned studies, Fochler (2016) examines "how researchers working in small and medium-sized biotechnology companies in Vienna, Austria, describe the cultural characteristics of knowledge production in this particular institutional space" (p. 259). To explore this question, the author conducted interviews with the founders and employees of several such startups. Drawing on a concept coined by Felt (2009), the main argument that Fochler develops in response to this question is that his informants viewed the startups in which they worked as "epistemic living spaces." More specifically, he argues that the researchers he interviewed often began working in or founding startups because of perceived deficiencies in working conditions in both academia and industry, and that "they considered their companies to be new spaces in which they could engage in research differently" (Fochler, 2016, p. 276)—an insight that can be neatly translated to agtech startups. However, he also cautions against overgeneralizing his findings. One reason Fochler gives for this is that the startups he studied had access to public funding in addition to venture capital, which mitigated the influence of venture capitalists on his informants' research, but which also depends very much on the national context in which a particular startup is located.

This dissertation combines these two bodies of literature (on agtech and foodtech startups, and on startups as spaces of knowledge production) in its examination of a single agtech startup. This means that the dissertation is attentive to the ways in which the agtech startup FLORA shifts what is considered to be a problem in the agricultural sector as a function of its technological solution, while at the same time taking the startup seriously as a space in which in part highly specialized individuals engage in the production of agriculturally relevant knowledge. Phrased as a sub-question, this dual concern with agtech startups could be expressed as follows: How does the agtech startup FLORA transform food security into a problem that can be solved by means of digital technology, and how does the team of the startup produce agriculturally relevant knowledge in this process?

Agriculture apps and the appeal of little devices

PHYTØ is not the only app being developed for the agriculture sector but is one of a growing group of agriculture apps, most of which promise to contribute to food security in one way or another. Whether one wishes to rent a tractor, plan a crop rotation, predict the harvest or—to stay on topic—recognize plant damages, there is an app for that. In this section, I review different texts that describe this phenomenon in order to derive a hypothesis regarding the particular role of mobile apps in contemporary agriculture that will be explored in this dissertation.

The idea of developing mobile services for farmers dates back to a time before the advent of today's smartphones. More specifically, agriculture apps for smartphones can be seen as successions of older, less sophisticated agriculture apps and SMS-based services for non-Internet-enabled feature phones. A famous example of such a historical precursor to today's agriculture apps is the service "Nokia Life Tools," or simply "Nokia Life," which was launched in India in 2009 by the eponymous Finnish telecommunications company. As one company executive was quoted in a Forbes article shortly after the launch, the goal of Nokia Life was to "seek out new service opportunities for Nokia where none exist […]."[16] In other words, Nokia sought to capitalize on the increasing penetration of cell phones among India's rural population by using these phones as a means to sell new services. A little further on in the same article, the exact nature of the services Nokia had in mind is summarized as follows:

> "Life Tools, a feature that's embedded in some handset models, serves like a text-message-based newswire service across three categories: agriculture, entertainment and education. So if a corn farmer subscribes to the agricultural newsfeed, he'll get text messages throughout the day on corn prices and corn-related news. 'We have a small editorial desk in each market collecting real-time data,' says Kanjilal [the head of Nokia's emerging-market services division at the time]. These staffs collect and validate information, then customize it according to region and crop, targeting it to the needs of each subscriber. Charging up to $1.20 for a monthly subscription for agricultural news, Life Tools in India now covers more than 275 crops in 18 states."

In short, Nokia was developing a new information-based service that the company planned to sell to farmers in the form of a monthly subscription. The above description of this service is revealing because it shows a striking similarity between Nokia Life and many of today's agriculture apps. This similarity lies in the fact that proponents of agricultural apps and SMS-based information services for farmers generally envision the transfer of agricultural knowledge as a linear and frictionless process.

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[16] Forbes. (2009, November 6). *Nokia's Emerging Hope.* https://www.forbes.com/global/2009/1116/wireless-singapore-jawahar-kanjilal-nokia-emerging-market.html?sh=5aa6ecaa259c

In the case of Nokia Life, however, things turned out differently. At first, everything looked promising: After the pilot phase in India was declared a success, Nokia Life was also launched in Indonesia, China, Nigeria, and Kenya.[17] According to the company, this led to the service having over 100 million users at its peak. Yet, despite this considerable expansion, the project was unexpectedly discontinued in 2013. Nokia's 2013 annual report explained this decision as follows:

> "At the end of 2013 we had to make some difficult decisions regarding Nokia Life and Life+. The partner ecosystem around the service was evolving rapidly from SMS to an application-centric approach as smart phones came down in price and with data subscriptions becoming increasingly available for affordable phones. With the changing environment, we made a strategic decision to discontinue the Nokia Life and Life+ services […]."[18]

Hence, the creators of Nokia Life had not anticipated the sudden competition that smartphone-based information services would pose to their business model, which ultimately caused them to abandon it. While this strategic withdrawal by Nokia is a clear indication of the rapid rise of agriculture apps for smartphones, it should not be misinterpreted as a sign that these apps have completely replaced apps and SMS-based services for feature phones. Rather, the world of agricultural apps must be seen as one in which smartphone apps, apps for feature phones, and SMS-based services coexist to this day.

This coexistence has been documented in numerous reports published by public and private organizations in an effort to inventory and typologize the ever-growing number of agriculture apps. To provide an example, as early as in 2012, economists at the World Bank published a 400-page report in which they examined 92 smart- and feature phone apps for agriculture and rural development. In a nutshell, the report's analysis consists of the definition of a five-part typology[19] and a subsequent assignment of the apps considered to the corresponding types. In addition, the report presents fifteen more detailed case studies, distinguished by the fact that they are based not only on desk research but also on field visits. Against the backdrop of this

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[17] GSMA Mobile and Development Intelligence. (2013). *Nokia Life.* https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2016/02/Case_Study_-Nokia_Life.pdf

[18] Nokia. (2013). *Nokia People & Planet Report 2013*. https://www.nokia.com/sites/default/files/2018-12/nokia_people_planet_report_2013.pdf

[19] This typology consists of "agriculture," "resource management," "labor, migration, and human development," "governance and political issues," "rural finance, infrastructure, and information and communication technology."

analysis, the authors formulate an optimistic forecast that, similar to the promises surrounding Nokia Life, highlights the ability of agriculture apps to seamlessly provide vital information to a large number of people in rural areas in developing countries, and thus significantly improve their quality of life:

> "The dynamic growth of mobile communications technology is creating opportunities for economic growth, social empowerment, and grassroots innovation in developing countries. One of the areas with the greatest potential impact is in the contribution that mobile applications can make to agricultural and rural development […], by providing access to information, markets, and services to millions of rural inhabitants. For both agricultural supply and demand, mobile phones can reduce waste, make delivery more efficient, and forge closer links between farmers and consumers" (p. i)."[20]

Besides telecommunications companies and international organizations, particular fields of research have also found a special interest in agricultural apps, most dominantly development economists. To cite a prominent example, in a 2019 Science article Fabregas, Schillbach, and recent Nobel Laureate Kremer review existing research on the provision of agricultural extension services via feature phones and smartphones. Building on this review, they make an optimistic assessment as to the potential of these technologies to positively affect the lives of farmers, particularly with regard to smartphone-based services. As they put it:

> "There is good reason to believe that emerging digital technologies can improve the functioning of agriculture markets at a very low cost per farmer. […] Mobile phones, particularly GPS-enabled smartphones, facilitate the provision of tailored information. Recommendations for agrochemical inputs that address specific soil conditions on the basis of digital maps can improve yields while reducing environmentally harmful and wasteful use. Messages can target specific areas with reported pest outbreaks or be customized to other local conditions such as market prices. Farmers can tailor their investment decisions to expected weather patterns and benefit from improvements in weather forecasting. Customized information allows farmers to choose language, dialect, or literacy levels. Mobile technologies can also provide reminders and other nudges to address behavioral biases." (Fabregas et al., 2019, p. 1)

Yet despite this broad endorsement of smartphone apps for farmers, the authors are hesitant to overgeneralize their assessment. The reason for this is that they also found that "market

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[20] Qiang, C. Z., Kuek, S. C., Dymond, A., Esselaar, S. (2012). *Mobile Applications for Agriculture and Rural Development.* The World Bank Group. https://openknowledge.worldbank.org/handle/10986/21892

failures" limit the ability of such services "to reach socially efficient scale" (ibid.), where by market failures the authors mean, for example, that the provided information is too technical, that farmers are unwilling to pay for the provided services, or that commercial providers may offer "biased" information to sell more inputs than actually necessary. Similarly, anthropologists working on ICT-enabled mobile extension services have shown that an overly scientific and insufficiently practice-oriented conceptualization of knowledge on the part of the providers of such services can result in the intended mediation of knowledge not taking place (Stone, 2011). No matter what disciplinary lens one chooses, the bottom line remains the same: Despite high expectations for and investments in mobile extension services for farmers, these extension services do not always achieve the desired results, for which there are multiple reasons, most of which are still poorly understood.

Besides the economic potential that development economists, politicians, and actors from the industry see in agriculture apps, this dissertation assumes that there is another important reason for the proliferation of these technologies in recent years that exceeds economic reasoning. This reason is quite simply that agriculture apps, when downloaded to a smartphone, are relatively little. This consideration is inspired by an issue of Limn magazine that is concerned with a recent trend in the fields of development and humanitarianism, namely the proliferation of "little development devices and humanitarian goods" (Collier et al., 2017). Although said issue is explicitly concerned with the fields of development and humanitarianism, its core argument translates well to the field of agriculture (not least because there is much intellectual, and material overlap between these areas). The way the authors frame it, the early 21st century has seen a proliferation of small technologies for development and humanitarian purposes such as water filters, solar lanterns, malaria test kits, water filtration systems, or sanitation devices. This observation prompts them to ask the following question, among others:

> "What does the proliferation of such small devices tell us about the contemporary state of 'development' and 'humanitarianism' as governmental projects, particularly when viewed in contrast to the massive modernist projects of previous decades?"

One important argument they formulate in response to this question is that these little devices do not happen to be little by mere coincidence. Instead, they argue that their littleness should be interpreted as a reaction to ongoing criticisms targeted at the large-scale development projects of the post-World War II era (e.g., dams, power plants, road networks), and the classical modernization paradigm that underpinned them. As the authors explain, "[w]ithin this classic modernization paradigm, a collective actor (often the state) sought to achieve broad structural transformation that benefitted the nation or ‘the public’ as a whole” (p. 2). However, the authors continue, these interventions often failed to deliver on the promises associated with them, making them the object of “sustained and polymorphous critiques” (ibid.). In this sense, they specify their argument that little development devices and humanitarian goods represent a counter-trend to these large, long-term projects, frequently targeted at entire populations, by stating that they are “designed to achieve immediate, measurable, and verifiable results and rely on individuals or communities as agents of development and arbiters of value” (ibid.).

It does not require a great deal of abstraction to translate this concern with little development devices and humanitarian goods to the realm of agriculture. The external conditions seem to be in place: Contemporary agriculture is marked by a history of large-scale, highly controversial modernization projects, such as, most famously, the “green revolution,” and the associated construction of CGIAR research centers in various relevant climate zones (Fitzgerald, 1986). At the same time, contemporary agriculture witnesses a proliferation of little, often digital, devices such as soil sensors, GPS cattle trackers, drones, or apps—a proliferation of little agriculture devices, so to speak. Yet, the consideration that the littleness of these little agriculture devices does indeed constitute a reaction to agriculture’s controversial past still remains to be put to test. The dissertation will explore this possibility by addressing the following second sub-question: How exactly does the little agriculture device PHYTØ respond to agriculture-related controversies of the past?

Case

To study the role of agriculture apps in the pursuit of food security, the dissertation undertakes a qualitative single-case study (Creswell, 2007; Yin, 2013). As indicated earlier, the main object of this case study is the agriculture app PHYTØ. Another closely related object of the case study that allows to examine the same process on a different analytical level is the agtech startup FLORA. This section briefly introduces these two objects, describes their interdependence, and some of the changes they have undergone over time. Based on this, the section proposes that the dissertation be considered as a case study of an agricultural app in the making.

FLORA, an agtech startup

A first important object of this case study is the agtech startup FLORA. It provides the organizational setting in which the agriculture app PHYTØ is predominantly developed. FLORA began as a project of two geography PhD students in 2014. Officially, the startup was founded in 2015 as a spin-off of their alma mater located in a medium-sized German city. Besides the two PhD students the founding team consisted of a group of five other people who knew each other either from their studies, from joint PhD research projects, or from working in a self-founded NGO that sought to popularize low-tech and organic agriculture in several West African countries.

At first the founders did not necessarily intend to turn their project into a venture capital funded startup. Rather, they thought about turning PHYTØ into a "crowdsourcing science" project or monetizing the app in the field of development cooperation, to which they maintained professional connections. Eventually, however, they were encouraged through an entrepreneurship scholarship program from the German government to transform their project into a startup, which gave great momentum to the development of PHYTØ.

In December 2016, FLORA raised its first round of venture capital funding in the amount of 1.1 million euros. In April 2017, the startup raised another round of funding for an undisclosed amount. In January 2018, FLORA succeeded in raising 4.5 million euros in venture capital, followed by €6.6 million in November 2019. Lastly—for the time being—FLORA raised another 5 million euros in July 2020. As summed up on the business platform Crunchbase, by 2020, FLORA had thus raised five rounds of funding with an estimated aggregate volume of approximately 20 million euros (including non-disclosed financing) from venture capital firms in the USA, China, Russia, the UK, and Germany, among others.

As more and more rounds of venture capital were raised, FLORA's spatial and personnel setup evolved as well. While the co-founders initially worked out of a small office in their university town, when they raised their first round of venture capital, they moved to a startup incubator which was operated by a venture capital firm in a major German city. At the same time, the startup hired its first employees, who were specialized in app design, machine learning, or environmental sciences. With further rounds of funding, the startup continued to expand, moving first from the incubator to an office of its own, then to bigger office, and later opening two regional offices in India, a country that had successively emerged as the startup's target country. Once again, this spatial expansion was accompanied by the recruitment of new employees, some of them highly specialized. After its fifth round of venture capital funding, FLORA even acquired another startup called INPUT-ZONE to absorb its digital distribution infrastructure for agricultural inputs in India. As a result of these efforts, at the time of writing this subsection (mid 2022), FLORA's website reports that the startup has 200 employees distributed between its headquarters in Germany and its regional offices in India, with the trend rising.

As in most companies, there are different departments or “teams” within FLORA. This dissertation focuses on the work of the “co-founders,” the “machine learning team,” the “plant team,” and the “product team.” Teams that are not considered in detail are for example the “accounting team” or the “marketing team.” Strictly speaking, the co-founders are not one of FLORA’s official teams. However, they share a set of experiences (e.g., writing business plans, creating pitch decks, interacting with investors) that makes them a worthwhile group to analyze within the startup. In addition to the work of these teams, the dissertation discusses several other workers associated with FLORA who play various intermediate or marginal roles in the operations of the startup such as “picture hunters,” “expert users,” or freelancers who sort pictures. Lastly, it should be noted that the dissertation does not address the teams that formed after the acquisition of INPUT-ZONE, since data collection had already been terminated by that time.

PHYTØ, an agriculture app

As mentioned before, the central object of this dissertation is the agriculture app PHYTØ itself. Like FLORA, PHYTØ has undergone numerous changes over the years, which will be unpacked in more detail in the course of this dissertation. Given these malleable boundaries of PHYTØ it seems most accurate to define the object of this dissertation as an agriculture app in the making. This means that the dissertation understands PHYTØ not as a fixed object that could be captured by a firm definition, but as an emergent reality that is subject to continuous change. This section briefly presents some features of PHYTØ that have remained relatively constant over the years—at least when viewed from a distance—in order to provide a basis for further consideration of the concrete methodology that underlies this dissertation.

The main feature for which PHYTØ has become known is the so-called “Crop Scan.” This name refers to PHYTØ’s “automated image recognition,” that is, the app’s ability to detect plant damages based on digital images of their symptoms via image processing algorithms. The images needed to develop these algorithms either come from PHYTØ users themselves or are collected by specialized FLORA employees in the field. Through this approach, over the years, the number of plant damages and crops that PHYTØ’s image recognition covers has increased steadily. To the point that, at the time of writing this subsection (mid 2022), FLORA’s website reports that PHYTØ can diagnose 500 plant damages on a total of 30 different crops. In parallel, the quality or “accuracy” of these diagnoses has continuously improved, so that PHYTØ’s pure diagnostic capabilities now exceed those of most human plant pathologists in a direct comparison, which the start-up has tested in a field trial with the plant pathologists of a major agricultural machinery manufacturer, among others. Against this background, the website continues, PHYTØ has now approximately “70,000 daily active app users,” and performs “1 diagnosis every 2 seconds.” Furthermore, it is stated that the app is “[a]vailable in 150 countries and 18 languages,” with the majority of users being based in India.

Another crucial function of the Crop Scan is that after a successful diagnosis, the feature provides its users with pesticide recommendations. As will become clearer throughout the chapters, the relationship of FLORA to pesticides has changed markedly over the years. However, one position that has gradually solidified among the PHYTØ developers is that the app is supposed to be “impartial,” by which they mean that it is meant to recommend both chemical and biological pesticides (if available), leaving users to make the final choice. Apart from these pesticide recommendations, the app also informs users about other crop protection measures that do not require the application of substances (e.g., removing infested plant parts) as well as preventive measures (e.g., maintaining a high number of different varieties of plants around fields).

Another important feature of the app, although less frequently used by users, is the “PHYTØ Encyclopedia” or “Encyclopedia” for short. As the name suggests, this feature consists of a digital encyclopedia where users can look up the information that FLORA has prepared regarding the plant damages covered by PHYTØ, on demand, that is, without having received a Crop Scan diagnosis beforehand. One advantage that the encyclopedia offers users compared to the Crop Scan is that its content can be stored on one’s smartphone and thus be used offline, for example, in regions where mobile internet is not available.

Yet another feature of PHYTØ, which is also not used as much as the Crop Scan is the “PHYTØ Forum” or “Forum” in brief, an online forum where PHYTØ users are invited to share their knowledge about agriculture and crop protection. Besides regular users, this forum is also populated by expert users, that is, paid specialists who answer the questions of regular users. As such, the forum serves an important function in maintaining PHYTØ’s diagnostic integrity, in that users for whose images the Crop Scan did not generate an unambiguous diagnosis are referred to the forum where expert users ideally resolve the diagnostic problem through human judgment.

Leaving PHYTØ aside for a moment, following the acquisition of INPUT-ZONE described in the previous subsection, FLORA has developed an additional application called MERCHANT, which is aimed at pesticide dealers rather than farmers. This app also plays a non-negligible role in the case study, but not as its central object. Instead, MERCHANT is viewed as a necessary means to develop a viable business model for PHYTØ, which remains FLORA's flagship technology. As one of FLORA's PowerPoint presentations for onboarding new employees puts it, the MERCHANT app is a "B2B e-commerce platform" meant to provide users (retailers) with a broad range of products such as pesticides, fertilizers, and seeds. In other words, the app provides a digital infrastructure to make it easier for retailers of pesticides and other inputs to buy products from input producers. After a successful diagnosis by the Crop Scan, farmers are now connected with stores of MERCHANT users in the vicinity of their farms to arrange the transaction of the corresponding product. For both farmers and retailers this service is free of charge, with FLORA extracting revenue by levying commissions on the additional sales of input producers that are brokered by the startup.

Methodology

This section explains the methodology employed in this dissertation to examine the case of PHYTØ. The section begins with a theoretical reflection on the dissertation's understanding of criticism. The section then discusses the specific understanding of ethnography on which the empiricism of this dissertation is based. Finally, the section presents the concrete research design and the methods used to conduct this empirical work.

A matter of concern

To begin with a personal anecdote: After my first empirical exposures to PHYTØ my thoughts about the app constantly and persistently wavered between an overly enthusiastic and an overly critical position towards it. "Maybe it's true," I thought some days, "maybe the app really does make an important contribution to achieving food security!" However, this pleasant thought typically did not last long and was usually quickly supplanted by a less pleasant thought that went roughly like this: "Maybe it's all a lie, maybe the app is causing nothing but exploitation, hunger, and pollution!" Interestingly, yet not coincidentally, the same poles can be found in most of the strands of literature reviewed above, be it literature on digital agriculture, agtech startups, or agriculture apps. However, the longer I studied PHYTØ and the more I was given the chance to watch the FLORA team at work, that is, the more I followed the app in the process of its creation, the clearer it became that there are many more nuances to it than this binary suggests. As I will explain in this subsection, in trying to evade this limiting binary and put the finer nuances that lie beneath it into words, it has helped me to conceptualize PHYTØ as a "matter of concern" (Latour, 2004).

Latour has coined the concept "matter of concern" to encourage a "new realism" (Flatscher & Seitz, 2018, my translation) in debates about scientific objects and other objects of public interest. Situating himself in the pragmatist tradition of James (e.g., 1975), Latour's declared goal in said essay is to nullify two critical positions that he estimates to account for "90 percent of the contemporary critical scene" (p. 237)—two positions that bear a marked resemblance to the two positions I outlined above. He calls these positions the "fact position" and the "fairy position." With the former, Latour refers to the reduction of objects to mere facts "in the sense of a naïve, reductionist positivism" (Flatscher & Seitz, 2018, p. 12, my translation). With the latter, he refers to the reduction of objects to fetishes or fairy tales "in the sense of a naïve social constructivism" (ibid.). Distancing himself from these two positions, Latour drafts a third critical position, which is not concerned with reduction, but, as he puts it, with assembling, gathering, and care:

> "The critic is not the one who debunks, but the one who assembles. The critic is not the one who lifts the rugs from under the feet of the naïve believers, but the one who offers the participants arenas in which to gather. The critic is not the one who alternates haphazardly between antifetishism and positivism like the drunk iconoclast drawn by Goya, but the one for whom, if something is constructed, then it means it is fragile and thus in great need of care and caution" (p. 248).

Applying this alternate critical position to the research endeavor of this dissertation means acknowledging that PHYTØ's technical capacities (e.g., recognizing plant damages) and its political capacities (e.g., contributing to food security) are constructed, while at the same time being empathetic to the careful work that goes into this construction. In more practical terms this means that analyzing PHYTØ as a matter of concern requires the researcher, me in this case, neither to buy into the statement "PHYTØ will feed the world" too easily ("fact position"), nor to debunk it from the outset as nothing but a myth ("fairy position"). Instead, the analytical task is to trace through which material and immaterial acts of construction FLORA and the startup's extended network arrive at the conviction that PHYTØ does indeed feed the world, or in attenuated form, that PHYTØ does contribute to achieving global food security.

A multi-sited and multi-situated ethnography

Beyond approaching PHYTØ as a matter of concern, the specific methodology through which I study the app draws on a combination of two methodological propositions, namely "multi-sited ethnography" (Marcus, 1995), and "multi-situated app studies" (Dieter et al., 2019). This section will briefly introduce these two propositions and show how their combination lends itself to the analytical project of this dissertation.

In short, while ethnography in the Malinowskian tradition has long assumed that analyses should be based on prolonged data collection in one clearly delineated field site, Marcus was one of the first anthropologists to spell out a methodological counter-proposition that broke with this assumption. Marcus' main argument was that there are social phenomena that cannot be captured by concentrating on a single site. To build this argument, his paper performed a review of ethnographic studies that, while not self-described by their authors as multi-sited ethnographies, represented, in Marcus's view, what he conceived of as such. Marcus summarizes the theoretical and methodological cohesion of this body of ethnographic research as follows:

> "The other, much less common mode of ethnographic research […], now often associated with the wave of intellectual capital labeled postmodern, moves out from the single sites and local situations of conventional ethnographic research designs to examine the circulation of cultural meanings, objects, and identities in diffuse time-space. This mode defines for itself an object of study that cannot be accounted for ethnographically by remaining focused on a single site of intensive investigation. […] This mobile ethnography takes unexpected trajectories in tracing a cultural formation across and within multiple sites of activity […]" (p. 96).

As postmodern influences of that ethnographic tradition, he cites, among others, Foucault's (1970) concept of heterotopia, Deleuze and Guattari's (1988) concept of the rhizome, or Haraway's (1985) concept of the cyborg. In more operational terms, Marcus goes on to synthesize the practical procedure for conducting a multi-sited ethnography as follows:

> "Multi-sited research is designed around chains, paths, threads, conjunctions, or juxtapositions of locations in which the ethnographer establishes some form of literal, physical presence, with an explicit, posited logic of association or connection among sites that in fact defines the argument of the ethnography" (p. 105).

Beyond these practical suggestions for designing multi-sited ethnographies, the last sentence of the quote is particularly crucial to understanding Marcus' methodological project. More specifically, the sentence speaks to the idea of letting ethnographic argumentation be guided not by "macro-theoretical concepts and narratives" (p. 96), but by the research object itself, and by how it is unfolding across multiple sites.

However, Marcus goes even one step further in his methodological description by pointing out that "[m]ulti-sited ethnographies define their objects of study through several different modes or techniques" (p. 106). As examples of those modes or techniques he cites "follow the people" (p. 106), "follow the thing" (ibid.), "follow the metaphor" (p. 108), "follow the plot, story, or allegory" (p. 109), "follow the life or biography" (ibid.), and "follow the conflict" (p. 110). As will become clearer throughout the chapters, I used several of these techniques in this dissertation without necessarily planning it in advance. Nevertheless, the most important technique for the present research project, which had been settled from the outset, was the second one, that is, "follow the thing." The suitability of this technique for the project of studying an app in the making becomes clearer in the next quote from Marcus, in which he summarizes that technique:

> "This mode of constructing the multi-sited space of research involves tracing the circulation through different contexts of a manifestly material object of study (at least as initially conceived), such as commodities, gifts, money, works of art, intellectual property" (pp. 106-107).

As examples of studies that have skillfully implemented this technique, Marcus cites, for example, Mintz's (1986) cultural history of sugar or Latour's (1993) analysis of the role of microbes and machines in the work of Louis Pasteur. In a similar vein, this dissertation follows PHYTØ through FLORA's various offices and into the field.

Nevertheless, as other researchers—primarily media scholars—have argued, "following the thing" in Marcus' sense is not enough to adequately capture the socio-technical worlds that apps open up (Dieter et al., 2019). More specifically, these authors argue for what they call "multi-situated app studies." To this end, they delineate their approach from Marcus' credo to "follow the thing" and suggest instead to investigate apps in a more stationary fashion, that is, from in front of a desktop or a smartphone display. Dieter et al. (2019) describe this methodological demarcation in the following terms:

> "One might draw a contrast, in this respect, with ethnographic approaches to global commodities that aim to 'follow the thing' across multiple sites or locales (Marcus, 1995). Since apps exist as digital objects within a technical milieux, it is less a case of following an app across 'sites' than of situating and re-situating apps drawing from a number of unique affordances that are available to the researcher" (p. 2).

By “situating” and “re-situating,” the authors mean studying apps in different “infrastructural settings” by which in turn they mean different computer- or smartphone-based empirical entry points. As examples of such infrastructural entry points, in the article they go into more detail about “app stores” (p. 2), “app interfaces” (p. 4), “app packages” (p. 7), and “app connections” (p. 8). In this dissertation, especially the second approach, app interfaces, plays an important role, because it allows to trace the continuous changes of the relation between PHYTØ and its users that characterize the trajectory of the app.

Practical research design, and methods

Overall, the dissertation follows PHYTØ over a period of eight years (2014-2022), with the starting point defined by the moment when the co-founders had the first idea for the app. To follow PHYTØ, I used different methods: First I conducted ethnographic fieldwork in Germany and India (13 weeks). Second, I conducted semi-structured interviews with FLORA’s staff and other people associated with the startup (34 interviews). Third, I analyzed a vast array of internal and public documents, as well as audiovisual materials collected on the internet. The purpose of this section is to explain this research design and the methods used to implement it in more detail.

The backbone of the data collection for this dissertation consisted of ethnographic observations conducted in FLORA’s offices in Germany and India, and while shadowing employees of the startup in the field as they interacted with farmers. In total, I conducted thirteen weeks of ethnographic observations within the startup. To take a step back, I was first introduced to FLORA by my former neighbor, a media artist and programmer who was friends with the head of the startup’s marketing team. Once it became clear that FLORA was indeed a good fit for my research project, and that the team of the startup was generally open to ethnographic research (e.g., one of the co-founders was herself an anthropologist by training), I undertook two separate research visits to the startup’s headquarters in October and November 2018 to get familiar with the organization, its general workflow, and its day-to-day problems. Equipped with the data and the preliminary results of these first two research visits, I undertook a longer research visit to FLORA’s two Indian offices in January and February 2019. As indicated earlier, in the course of this visit, I also had the opportunity to observe FLORA staff interacting with farmers in the field. After an initial analysis of the data that resulted from this field research in Germany and India, I undertook another extended field visit to FLORA’s German offices that spanned across September and October 2019. During the entirety of this fieldwork, I kept detailed field notes on the activities of the various members of the startup's team with whom I interacted during that time. In the subsequent analysis and writing process, these notes were enriched with the data that my other methods yielded, in order to create what Geertz calls a "thick description" (1973) of the case at hand.

Another important pillar of the data collection undertaken in the course of this dissertation consisted of semi-structured interviews with members of the FLORA team itself, and people from the startup's extended network. In total, 34 formal interviews were conducted, ranging in length from 30 minutes to two hours. The interviewees can be divided into the following groups: The co-founders (7 interviews), additional management staff (2 interviews), software developers and data scientists (8 interviews), the "plant team" (5 interviews), the "product team" (2 interviews), employees from FLORA's regional offices in India (5 interviews), individuals from the extended FLORA network, mainly researchers associated with ICRISAT (5 interviews). In a few cases, interviewees did not want to be recorded, in which case the audio recording was replaced by a written protocol. All interviews were based on pre-prepared, yet flexible, guides that typically touched upon the interviewees' professional backgrounds, their day-to-day work at the startup, the evolution of their job responsibilities over time, as well as tensions they had to deal with in their work (e.g., tensions regarding the risk of recommending chemical pesticides with an app). For some of the interviews, especially those that revolved around more technical tasks, stimuli were used, usually PowerPoint presentations developed by the interviewees themselves to help other members of the FLORA team or third parties understand their work area. Besides that, I conducted a number of more informal interviews for which I did not prepare an interview guideline as they arose spontaneously. In addition, an attempt was made to conduct interviews with farmers in India, some of whom used PHYTØ, with the help of an interpreter provided by FLORA. Unfortunately, the quality of the interpretation was insufficient, so the resulting data is not used in this dissertation.

The third important source of data on which the empirical analysis of this dissertation is based consisted of documents and audiovisual material. These documents are, on the one hand, dozens of publicly available documents such as newspaper articles, online articles, scientific articles, or institutional reports concerned with PHYTØ. On the other hand—thanks to the fact that FLORA granted me access to its Google Drive, that is, the startup's digital archive—the body of documents analyzed for this thesis equally consisted of a large number of documents that have been circulated within the startup at different points in time. These documents are of different nature and range from documents for onboarding new employees, and conceptual planning documents for new app features, over PowerPoint presentations for weekly team meetings, and instructions on how to behave in case of a Covid-19 infection, to old business plans, and current pitch decks. As agreed with the co-founders of FLORA, no competitively sensitive information from these documents will be disclosed in this dissertation.

The analysis of this data unfolded successively over the course of the writing process, and was inspired in part by Braun and Clarke's (2006) proposal of "thematic analysis." More specifically, through an iterative process, four themes or problems were identified that have occupied the developers of PHYTØ over the years, and that have thus greatly shaped, if not constituted, the emergence of the app. After identifying these themes, the three types of data described in this subsection were superimposed to create four analytical narratives that form the argument of this dissertation which will be presented in the next section.

Outline of the argument

So, how does PHYTØ feed the world? The present dissertation answers this question in four chapters. Each of these chapters discusses a problem that the developers of PHYTØ face in their daily work on the app, and which at the same time corresponds to a theoretical problem that emerges from the literature with which this dissertation enters into dialogue. As noted above, these arguments do not apply only to the case of PHYTØ. Rather, they contribute to a more general understanding of how agtech startups developing little agriculture devices, particularly digital ones, are addressing complex contemporary problems related to food and agriculture, including but not limited to food security. As this section will summarize, the dissertation argues that FLORA and comparable startups intervene into contemporary agriculture by (1) exploratively assetizing agtech, (2) selectively recognizing agricultural phenomena, (2) collectively enacting expertise, and (4) coherently representing users.

Chapter 1: Assetizing agtech

The first chapter explores how FLORA has turned PHYTØ into an "asset" (Birch & Muniesa, 2020) from which continuous revenue streams can be extracted. To address this question, the chapter reconstructs the trajectory of PHYTØ from the app's early phase as a student project in Germany to its late phase as a platform for brokering pesticide sales in India. The chapter shows that FLORA has succeeded in the "assetization" of PHYTØ by continuously and sometimes drastically changing itself and the app over the years. Moreover, the chapter shows that these changes were often unforeseen and resulted from the new associations the startup made along the way. Based on this insight, the chapter argues that the assetization of PHYTØ should be regarded as a process of "exploration" (Doganova, 2013), in which the socio-technical collective involved in the assetization process stabilized only over time through continuous confrontations between the technology to be assetized and the different social worlds with which it gradually came into contact. Despite this non-deterministic view on PHYTØ's trajectory, the chapter also documents the growing influence that venture capitalists exerted on the form and content of the app as funding rounds progressed. Based on this, the chapter specifies its argument and proposes to consider the trajectory of PHYTØ as a process of "exploratory assetization," by which it means an exploration process that is dominantly guided by venture capitalists searching a particular field (such as agriculture in this case) for untapped human and non-human actors from which to extract new revenue streams. In the case of PHYTØ, the chapter concludes, this exploratory assetization led to an approach toward food security (inscribed in the app) that increasingly centered on scaling up user numbers, incoming pictures, and pesticide sales (cf., Pfotenhauer et al., 2021).

Chapter 2: Recognizing plant pathology

The second chapter addresses the question of how FLORA constructs the image recognition algorithms deployed in PHYTØ. It examines how in this process—which is essentially a classification (Bowker & Star, 1999) process—certain aspects of plant pathology are singled out to be recognized by PHYTØ while other aspects of plant pathology are being neglected. Following Bechmann and Bowker (2019), the chapter argues that the construction of image recognition algorithms can be conceptualized as a sequence of "layers of knowledge production." Subsequently, the chapter identifies five such layers that make up the construction of PHYTØ's image recognition algorithms, namely "defining problems," "generating data," "preparing data," "shaping algorithms," and "representing results." Moreover, the chapter demonstrates that at each of these layers the phenomenon of plant pathology is subjected to various practices of "selection" (Lynch 1990) to render it algorithmically recognizable. The result of these practices is that the algorithms deployed in PHYTØ recognize some aspects of the phenomenon of plant pathology while at the same time not recognizing others—a condition that the chapter refers to as PHYTØ's selective recognition of plant pathology. In the attempt to discern a pattern in this selective recognition the chapter shows that PHYTØ is well suited for recognizing isolated plant damages on isolated crops, while largely neglecting what the chapter calls the "in-betweens" of plant pathology (e.g., differences between crop varieties, multiple plant damages in one leaf, severity of plant damages on leaves, spread of plant damages in the field). Based on this, the chapter concludes that PHYTØ's selective recognition of plant pathology, in its current state, appears to be especially conducive to more pesticide-intensive ways of farming, as the non-produced knowledge regarding the aforementioned in-betweens is particularly important for approaches to crop protection that advocate a reduction in pesticide use, such as integrated pest management (IPM), agroecology, or organic agriculture. In addition, it is important to emphasize that the chapter takes the position that this effect, which might be thought of as a bias in favor of pesticide use, is unintentionally inscribed into PHYTØ and not out of any dishonest intentions.

Chapter 3: Enacting expertise

Based on FLORA's frequently reiterated claim that the PHYTØ app itself is a "digital expert," the third chapter explores how the startup maintains this claim to expertise at a distance, that is, from the back office of the startup. On a theoretical level, the chapter draws from anthropological research on mobile extension (Stone, 2011), and argues that smartphone-based agricultural extension services, such as PHYTØ, should be understood as a collective "enactment" (Carr, 2010) of expertise. More specifically, the chapter argues that the FLORA team has so far succeeded in maintaining the enactment of expertise through PHYTØ by constantly aligning its own notion of adequate mobile extension with its users' notion of adequate mobile extension. In more practical terms, the chapter examines the work of the plant team, and identifies two successive phases in how its employees inscribe mobile extension services into the app. It shows that these phases differ in that they are characterized by both a different form and a different conception of expert advice: In the early phase of PHYTØ's mobile extension services, the plant team concentrated their work on providing users with lengthier text-based advice imbued with relatively narrow instructions on how to farm. However, FLORA gradually found that PHYTØ users showed little interest in these texts. The consequence of this was a shift in PHYTØ's approach to mobile extension. In other words, the limited interest of users in PHYTØ's text-based advice ushered in the late phase in the app's mobile extension services. In this phase the plant team focused its efforts more on providing users with a selection of brief pesticide recommendations (both biological and chemical), while not being explicit about which of the suggested crop protection measures, they deemed best. This new design of PHYTØ's mobile extension services captured the interest of PHYTØ users more effectively than the previous one. PHYTØ's instructions on how users should farm thus became less restrictive compared to the initial phase. Based on these insights, and borrowing from Henke's (2008) assessment of in-person extension as a "fundamentally conservative technique of social change" (p. 146)—caused by extension agents' continual concern about farmers denying them access to their fields—the chapter concludes that mobile extension services like PHYTØ may well be even more conservative techniques of social change.

Chapter 4: Representing users

The fourth chapter deals with the question of how FLORA generates knowledge about PHYTØ users. In theoretical terms, the chapter conceptualizes this knowledge production as a process of continuously generating "user representation" (Akrich, 1995) by means of different "user representation techniques" (ibid.). Following Akrich, the chapter assumes that the problem for developers of technologies such as PHYTØ is not to create user representations, but to align deviating user representations that arise during this process to create a coherent overall representation that can inform the development of the evolving technology. Empirically, the chapter shows that two types of user representation techniques are used within FLORA, those that operate at a distance (e.g., digital performance metrics) and those that operate in the field (e.g., prototype testing), to continuously generate new representations of PHYTØ users, that is, to produce knowledge about PHYTØ users. Based on this, the chapter goes on to demonstrate that within FLORA a dominant user representation prevails that portrays PHYTØ and MERCHANT users as a growing group of farmers and pesticide retailers who recognize the practical benefits of the apps and use them accordingly—a user representation that is strongly influenced by the expectations venture capitalists hold with regard to the startup. Along with this, it is equally shown that remotely generated user representations in particular are of great importance to investors, as they enable assessment of larger groups of users, while user representations generated in the field generally refer to individual users or small groups of users. Still following Akrich, the chapter subsequently identifies some of the "strategies" that the FLORA team developed to align deviating user representations with the startup's dominant user representation. These strategies include the adjustment of performance metrics, the hiring of expert users, or collectivization of experiences made with deviating users in the field and must be seen as a vital mechanism for sustaining the work on PHYTØ. The chapter concludes that FLORA's interactions with users suggest that as digital agriculture expands, the semi-fictional character of the user will increasingly conflict with the less fictional character of the small farmer (or the pesticide retailer respectively).

1. Turning an agriculture app into an asset

Summary of the chapter in French (for formal reasons): 1. Transformer une application agricole en asset

Le premier chapitre explore comment FLORA a transformé PHYTØ en un « asset » (Birch & Muniesa, 2020) à partir duquel des flux de revenus continus peuvent être extraits. Pour répondre à cette question, le chapitre reconstruit la trajectoire de PHYTØ de la phase initiale de l'application en tant que projet étudiant en en Allemagne jusqu'à sa phase tardive en tant que plateforme de médiation pour la vente de pesticides en Inde. Le chapitre montre que FLORA a réussi à « assetizer » PHYTØ en se modifiant continuellement et parfois radicalement, ainsi que l'application, au fil des ans. De plus, le chapitre montre que ces changements étaient souvent imprévus et résultaient des nouvelles associations que la startup a faites au fil du temps. Sur la base de cet éclairage, le chapitre soutient que l'assetization de PHYTØ doit être considérée comme un processus « d'exploration » (Doganova, 2013), dans lequel le collectif sociotechnique impliqué dans le processus d'assetization ne s'est stabilisé qu'au fil du temps, par le biais de confrontations continues entre la technologie à assetizer et les différents mondes sociaux avec lesquels elle est progressivement entrée en contact. Malgré cette vision non déterministe de la trajectoire de PHYTØ, le chapitre documente également l'influence croissante exercée par les investisseurs en capital-risque sur la forme et le contenu de l'application au fil des cycles de financement. Sur cette base, le chapitre précise son argumentation et propose de considérer la trajectoire de PHYTØ comme un processus « d'assetization exploratoire », c'est-à-dire un processus d'exploration principalement guidé par des investisseurs en capital-risque qui recherchent, dans un domaine particulier (comme l'agriculture dans le cas présent), des acteurs humains et non humains inexploités dont ils pourront extraire de nouvelles sources de revenus. Dans le cas de PHYTØ, conclut le chapitre, cette assetization exploratoire a conduit à une approche de la sécurité alimentaire (inscrite dans l'application) de plus en plus axée sur « scaling up » le nombre d'utilisateurs, des photos reçues et des ventes de pesticides (cf. Pfotenhauer et al., 2021).

Introduction

In recent years, investment in agtech startups has grown at an unprecedented pace. As documented in a report by the venture capital firm AgFunder published in 2019, the combined annual funding for agtech and foodtech startups totaled \$2.9 billion in 2012, \$5.7 billion in

2014, $8.6 billion in 2016, and $20.8 billion in 2018.[21] A few years later, in 2022, a subsequent edition of the same report announced a similarly drastic increase in funding. As the report put it, "[v]enture capital investors pumped $51.7 billion into agrifoodtech in 2021—an 85% increase over 2020."[22] Yet, how exactly do agtech and foodtech startups including the technologies they develop become objects of investment, and how does this process affect the agrifood systems it touches upon?

The present chapter takes on this very question. More specifically, it explores the question of how one specific agtech startup (FLORA) has managed to turn the technology it develops (PHYTØ) into an asset attracting ever new rounds of venture capital funding. The chapter advances the argument that the startup has succeeded in this "assetization" (Birch & Muniesa, 2020) by drastically transforming itself and the technology it has been developing over the years. As the chapter shows, these transformations were often unforeseen, resulting from the new associations the startup forged along the way. Based on this insight, the chapter specifies its argument, suggesting that the assetization of the agtech innovation at stake should be viewed as a process of "exploration" (Doganova, 2013) in which the socio-technical collective involved stabilized only over time through continuous confrontations with different social worlds. On a more general note, the chapter underscores that the successful assetization of PHYTØ was by no means a given and that it could just as easily have failed or turned out otherwise. Despite this non-deterministic view on the trajectory of FLORA, the chapter documents a rather drastic change in the orientation of the assetization process of PHYTØ as of the moment that venture capitalists took an interest in the startup, indicating the vital influence of this specific group of actors on the trajectory of the startup. Given this insight, the chapter refines its argument suggesting to consider the trajectory of PHYTØ as a process of "exploratory assetization," meaning a process in which an emerging technology is gradually turned into a device through which venture capitalists can explore particular sectors (e.g., agriculture) in the search for untapped human and non-human actors from which new revenue streams might be extracted. In the case of PHYTØ, the chapter concludes, this exploratory

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[21] AgFunder. (2019). *AgFunder agri-foodtech investing report.* https://research.agfunder.com/2019/AgFunder-Agrifood-Tech-Investing-Report-2019.pdf

[22] AgFunder. (2021, September 9). *Data snapshot: 2021 set to break new record for agrifoodtech investment; $24bn raised in H1.* https://agfundernews.com/agrifoodtech-investment-set-to-far-outpace-2020s-record-breaking-levels-hits-24bn-in-h1

assetization led to an interpretation food security (inscribed into the app) that increasingly centered on problems of scaling up user numbers, incoming pictures, and pesticide sales (cf., Pfotenhauer et al., 2021).

To develop this argument, the chapter is divided into five sections. The first section is a theoretical section that situates the chapter's research question in existing scholarship on agtech and foodtech startups before clarifying the analytical intricacies of the concept of assetization. The remaining four sections explore this research question empirically: Section two describes the beginnings of PHYTØ, that is, how the prospective co-founders of FLORA, still embedded in the context of their university, assembled a first functional version of the app. Section three elaborates how this technology allowed the FLORA team to get in touch with, and evaluate, different funding sources before finally opting for venture capital. Section four, illustrates how, at the request of their venture capitalists, the members of the FLORA team focused their efforts on greatly increasing the number of PHYTØ users, which they achieved by targeting the app almost exclusively at India. Lastly, section five, describes how the developers of PHYTØ eventually managed to turn the app into an asset by developing a business model that allowed them to extract a durable economic rent from the app. Overall, these empirical sections reconstruct the assetization process of PHYTØ over an eight-year period (2014-2022), where each section is differentiated by a delineable composition of the FLORA collective and a delineable status of the PHYTØ technology. The chapter closes with a conclusion wrapping up its main findings, and their contribution to the emerging body of social science and humanities scholarship on agtech and foodtech startups.

1.1. The assetization of agtech

This first section prepares the empirical analysis of the remaining chapter by providing some theoretical background. More specifically, the first subsection reviews existing literature on the trajectories of agtech and foodtech startups in relation to other more established actors in agrifood systems, namely Big Ag corporations, and financial-sector actors. Building on this, the second subsection situates the chapter in debates on "assetization" (Birch & Muniesa, 2020) and "exploration" (Doganova, 2013), before making the theoretical proposition that the development processes of PHYTØ ought to be regarded as processes of exploratory assetization.

1.1.1. Two perspectives on the trajectories of agtech startups

Given the rapid rise of agtech startups in recent years, a small but steadily growing group of social science and humanities scholars—some of whom have already appeared in the introduction—has begun to examine the different trajectories that these new companies are taking in relation to other, more established actors in agrifood systems. At this point, two of these perspectives on the trajectories of agtech startups will be presented, namely one that focuses on the relationship between agtech startups and Big Ag corporations (large producers of pesticides, fertilizers, seeds, or agriculture machinery), and one that focuses on the relationship between agtech startups and financial actors. These perspectives will help in the next step to narrow down the problem that the rest of this chapter will address.

The first perspective explores the relation between agtech startups and Big Ag corporations from a foremost politico-economic perspective. A common argument made by the respective scholars is that novel agtech devices (not exclusively developed by startups) serve to legitimize environmentally harmful actions of Big Ag corporations, thus strengthening their oligopolistic market positions (e.g., Duncan et al., 2021; Rotz et al., 2019). An important precursor to this argument can be found in Wolf and Wood's (1997) critique of the political economy of precision agriculture, in which the authors argue that the phenomenon "legitimates chemically-based agriculture in an era of rising environmentalism" (p. 180). Another, more startup-centered, contemporary adaptation of this criticism may be found, for example, in a recent study by Bronson and Sengers (2022), in which the authors explore the connections between smaller agtech startups, Big Ag corporations (Bayer/Monsanto, BASF, John Deere, etc.), and Big Tech (Google, Facebook, Amazon, etc.). One important argument the authors make in the article is that because of the numerous controversies Big Ag has stirred up in the past (GMOs, glyphosate-induced cancer, insect die-offs, etc.), the respective companies would now attempt to change their public image for the better. More specifically, as Bronson and Sengers phrase it, they would attempt to change their image away from classical producers of seeds, chemicals, or heavy machinery and towards "data corporations" in the spirit of Big Tech. In this transformation, the authors continue, agtech startups play a central role. This is because, to make the shift to data corporations, Big Ag companies commonly acquire smaller agtech startups and integrate their digital products or services into their own portfolios. A prominent example the authors invoke to illustrate this point, is "The Climate Corporation," a company that was founded in 2006 by two former Google employees, purchased by Monsanto in 2013, and consequentially absorbed by Bayer in 2018. While the company initially sold weather insurance to farmers, it is now best known for its product "Climate FieldView," a decision support system, that analyzes historical crop data, field data, and weather data to generate paid advisory services for farmers. Viewed through the lens of Bronson and Sengers' argument, however, the acquisition of The Climate Corporation fulfilled not only an economic but also a symbolic purpose for Bayer/Monsanto, namely that of discursively distancing the company from its increasingly controversial core business of producing and selling chemicals and seeds. To put it in the words of the authors:

> "Currently Bayer/Monsanto appears to identify as a data corporation […]. Besides the money to be made from the sale of data-based decision systems and the data themselves, there may be other more symbolic ways to profit from farm big data. Bayer/Monsanto's digital strategy enables the company to resignify itself away from seeds and chemicals amidst high-profile public questioning about the industrialized approach to agriculture" (p. 4).

In short, one could thus synthesize that these studies highlight that agtech startups, despite touting themselves as spearheading a radical transformation of agrifood systems, generally have to adapt to the existing politico-economic logics of the agricultural sector, which makes them susceptible to being aligned with the interests of by Big Ag corporations.

A second important perspective to look at agtech startups is opened up by scholars concerned with the financialization of food and agriculture, that is, with the increasing influence of "private financial actors in the food system" (Martin & Clapp, 2015, p. 550). In this perspective, agtech startups are regarded as one of many objects in which financial actors invest for reasons of financial accumulation. In summarizing the short history of this trend Prause et al. (2021) note that following the financial crisis in 2008, large-scale financial actors (e.g., investment banks, hedge funds, pension funds, private equity funds) increasingly invested in the agricultural sector as they began to conceive of it as a safe and thus attractive investment option to diversify their portfolios. As Clapp and Isakson (2018) point out, this development went hand in hand with a sharp increase in the amount of venture capital invested in agtech and foodtech startups. On the one hand, this capital came from conventional venture capital firms. On the other hand, it came from major agricultural input companies that began to establish in-house venture capital arms to fund startups that were aligned with their strategic interests. Leaving startups aside for a moment, a central question that scholars concerned with the financialization of food and agriculture grapple with is the question regarding the transformations required to turn specific elements of agrifood systems (e.g., crops, farmland, technologies) into attractive objects of investment. To offer one example for how scholars scrutinize such transformations: In a monograph on the financialization of farmland, Fairbairn (2020) describes how the agricultural practices orchestrated by financial actors differ from those of other, more classical, landowners:

> "Financial-sector actors […] have a set of motivations and obligations fundamentally different from those of other types of landowners, and this can affect the way that they treat their farms. Investor-owners may gesture toward their strong environmental or social values, but at the end of the day they will be judged on their economic performance" (p. 133).

As Fairbairn goes on to explain, in the case of financialized landownership, this economic performance hinges upon "larger-scale and more capital-intensive production" (p. 134.), among others, thus disqualifying certain forms of land use, such as "small-scale farming based on agroecological principles" (p. 135) almost a priori. Simply put, Fairbairn argues that the logic of financial-sector actors inscribes itself into the way contemporary societies practice agriculture. With this in mind, the debates on agtech and foodtech startups outlined in the introduction to this dissertation can be seen as an attempt to translate this concern with the growing influence of financial sector actors on agrifood systems from the issue of investment in land to the issue of investment in tech. "How is the increasing involvement of startups and venture capitalists in agrifood systems transforming these systems?" is one way to paraphrase one of the questions driving the researchers of the AFTeR project (Fairbairn et al., 2022; Fairbairn & Guthman, 2020; Reisman, 2021). As has already been discussed, answers given to this question by the respective scholars are that agtech and foodtech startups tend to foster acts of "technological solutionism" (cf., Morozov, 2013), that is, transforming complex problems into simpler technological problems, some of which are not problems at all, and "non-disruptive disruption" (cf., Goldstein, 2018), that is, innovations that do not produce the systemic transformations it would take to realize the world-saving narratives associated with these innovations. This chapter shares the view of these scholars that the approach of many agtech and foodtech startups to the problems that arise in agrifood systems can be seen as simplistic, and that this simplification often seems to be a result of the technologies available to these startups. Nonetheless, I would like to go beyond this critique to understand what exactly these startups are doing to agrifood systems if they are not really "solving" their problems or "disrupting" their markets. To this end, the chapter mobilizes an additional body of literature.

1.1.2. Assetization as exploration

This subsection expands on the two perspectives on agtech startups outlined in the previous subsection by suggesting to approach the development and commercialization of the technological device PHYTØ as a process of "assetization" (Birch & Muniesa, 2020), and as a process of "exploration" (Doganova, 2013). Subsequently, the subsection brings these concepts together and proposes to view the trajectory of PHYTØ as a process of "exploratory assetization," that is, an exploration process guided primarily by the interests of venture capitalists.

Closely related to debates on "capitalization" (Muniesa et al., 2017), debates around the concept of assetization have recently gained renewed momentum through an edited volume by Birch and Muniesa (2020). The key argument around which the contributions to said volume revolve is that the "dominant *form* that technoscientific capitalism affords is not the commodity but the asset" (p. 1), making capital investment, as opposed to market speculation, the predominant concern of the actors involved. An important difference to conventional debates on financialization that Birch and Muniesa spell out in the introduction to the volume is that assets do not have to be financial objects, which means that they can exist independent of financial markets. In their deliberately broad definition, an asset is "something that can be owned or controlled, traded, and capitalized as a revenue stream" (p. 2), implying that an asset "could be a piece of land, a skill or experience, a sum of money, a bodily function or affective personality, a life-form, a patent or copyright, and so on" (ibid.). It is the broadness of this definition that makes the concept of the asset so applicable to this chapter's concern with agtech. As Birch and Muniesa go on to specify, a common denominator of those who control assets is "to get a durable economic rent from them" (ibid.), where rent refers to an "extraction of value through ownership and control" (ibid.). Similar to Fairbairn's (2020) concern with the construction of farmland as an object of investment, Birch and Muniesa (2020) emphasize that assets are constructed, and suggest the central question: How do things become assets, then?" (2020, p. 2).

In response to this question, scholars concerned with assetization have begun to examine the manifold processes through which some of the objects that populate contemporary societies are turned into assets. To name but a few examples, scholars have reconstructed the assetization of objects ranging from pharmaceuticals (Roy, 2020), over seeds (Braun, 2020) and photovoltaics (Nadaï & Cointe, 2020), to data (Birch et al., 2021). One example that is particularly insightful for this chapter comes from Schneider (2021), who studies the assetization of food through emerging foodtech startups. As Schneider put it in an online lecture, one of the central questions guiding her research on foodtech startups reads: “How is food innovation turned into an asset warranting investment?” To pursue this question, Schneider examines different foodtech innovations in different empirical settings. As an example, in the online lecture referenced above, she presented research on investment conferences for foodtech startups, and the particular ways in which these events perform the future of food. Elsewhere, Schneider analyzes the narratives that foodtech startups develop on their websites or in interviews, and how these narratives redefine both the meaning and the materiality of “sustainable food” (2018). Taken together, then, in answering her research question, Schneider places much emphasis on the dispersed performative practices by means of which different startups attempt to transform different foodtech innovations into assets.

This chapter translates this concern with the problem of startup-driven assetization in agrifood systems to the realm of agtech but chooses a slightly different methodological angle. Rather than looking at snippets of several different innovation processes at once, the chapter is interested in reconstructing one cohesive assetization process—from the initial conception of the technology in question to the extraction of a durable economic rent from it. Correspondingly, the chapter asks: How did the agtech startup FLORA turn the technology PHYTØ into an asset, and what transformations did this process require of the actors involved?

As mentioned above, one core argument that the chapter develops in response to this question is that the assetization process of PHYTØ should be grasped as a process of “exploration” as defined by Doganova (2013). To clarify, Doganova coined the concept of exploration in response to widespread debates that conceive of the work of university-born startups or “spin-offs” as a form of “technology transfer.” As she puts it, this “transfer model” does not do justice to the trajectories of most of these companies as it generally assumes a fairly linear company-development while positing “the stable identity of that which is transported, and of the sites between which the transport takes place” (p. 444). In contrast, Doganova suggests to conceptualize the activity of these start-ups as acts of exploration. As she specifies it, a concern with startup-driven innovation as exploration is characterized by two important, analytical differences from the “transfer model”: First, an attention to the fact that “the temporal sequence and the causal links between exploratory activities and their outputs cannot be specified ex ante,” since “the results of exploration are not only distant in time, but also loosely coupled to their causes” (p. 445). Second, an attention to the fact that “the identities of the entities which explore and which are being explored are in the making” (ibid.). It is this attention to the mostly unforeseeable transformations enabling innovation processes which makes the concept of exploration so useful for the purpose of this chapter, that is, to examine how a startup gradually turned the technology it has been developing over a given period of time into an asset. As the chapter will show, the trajectory of PHYTØ also amounted to a process of exploration, in that the startup and the app continuously changed in interplay with the different social worlds with which they interacted. Despite this non-deterministic approach, the chapter will also show that over time, venture capitalists became the social world that exerted the greatest influence on the trajectory of PHYTØ. In other words, PHYTØ increasingly turned into a device that explored agrifood systems on behalf of venture capitalists in search of untapped human and non-human actors from which new, continuous revenue streams could be extracted—a process that I refer to as "exploratory assetization." In the case of PHYTØ, this process led to an approach to food security that increasingly centered on problems of scaling up user numbers, incoming pictures, and pesticide sales.

With this in mind, the following four empirical sections reconstruct the heterogeneous exploratory activities through which the socio-technical collective of FLORA has emerged over the years, and how it gradually succeeded in turning the agtech device PHYTØ into an asset.

1.2. Assembling a technology

The first phase in the assetization of PHYTØ revolved around the problem of assembling a functioning version of the app. This phase extended from the moment when two of the soon-to-be co-founders of FLORA had the first idea for PHYTØ (2014) to the moment when their newly assembled team succeeded in developing the first image processing algorithms to be deployed in the app (2015). Both legally and in terms of the team's self-image, the project was not yet a startup at this stage. Rather, the developers of PHYTØ conceived of their doings as "citizen science" or "crowdsourcing science" project with the goal of making expert knowledge freely available to a large public.

1.2.1. Identifying a problem

The first important step in assembling the PHYTØ app consisted of identifying a problem that lent itself to being solved. When the co-founders of FLORA recount how they became aware of this problem, they usually begin with the story of a research trip to the Brazilian Amazon region. As the story goes, in 2014 an interdisciplinary group of scientists from a conglomerate of German universities traveled to Brazil to investigate the relationship between different forms of land-use and anthropogenic climate change. Among these scientists were the geography PhD students Wanda and Kosmo—two of the soon to be co-founders of FLORA. In the research project, the two were responsible for excavating soil profiles and measuring soil carbon at different sites. Many of these sites were located on land that belonged to indigenous farmers. Hence, it was not uncommon for the PhD students to enter into dialogue with the local population.

When Wanda and Kosmo recount the founding narrative of FLORA, they usually describe how the farmers they talked to had little interest in their research on soil carbon. Instead, they were worried about a disease that was affecting their plants at the time, a disease which they referred to as "morto subito" (English: "sudden death"). If the two of them were really scientists, the farmers insisted, then surely, they could tell them how to cure morto subito. Yet, Wanda and Kosmo could not, at least not immediately. As Wanda recalled in an interview, the problem was that they did not know the "scientific name" of morto subito. With the scientific name, they would have been able to find a remedy against the plant damage in no time. Without the scientific name, Google only showed them "pictures of car accidents" whenever they entered morto subito in the search bar. However, eventually, with the help of their scientific supervisor, they found out that morto subito was a fungus of the genus "Phytophthora." Once they knew this, Wanda and Kosmo saw themselves in the position to recommend a suitable remedy against morto subito to the farmers.

In parallel to this chain of events, the two PhD students continued with the excavation of soil profiles for which they had originally come to Brazil. However, the problem of morto subito to which the local farmer had drawn their attention should continue to occupy them. The way FLORA's founding narrative frames it, this problem consisted of two subproblems. First, diagnosing morto subito, that is, finding the corresponding scientific name for the symptoms caused by the disease. Second, finding a remedy to treat the newly diagnosed plant damage. Undoubtedly, there would have been other ways to frame the problem of morto subito. For now, however, let it suffice to note that Wanda and Kosmo settled on the one described above, which should not let them go for the years to come.

1.2.2. Planning a solution

The second step in assembling PHYTØ consisted of planning a technical solution for the newly identified problem. In doing so, one specific scientific article played a decisive role. In an interview, Wanda recounted their first encounter with said article as follows: After the final conference of their research group, which took place in the city of Manaus, Kosmo, and herself, who had gotten married in the meantime, spent their honeymoon in Brazil. During the honeymoon, Kosmo occasionally read scientific articles on questions related to machine learning. This interest in machine learning did not come out of nowhere but resulted from the division of labor in their PhD project. As Wanda recalled it:

> "I was more concerned with the sampling and the laboratory work, and Kosmo started programming and modelling, building models that were supposed to represent soil processes, and he really became some kind of a nerd."

One of the articles that Kosmo was reading during their honeymoon was a 2013 review paper by Arnal Barbedo titled "Digital image processing techniques for detecting, quantifying and classifying plant diseases." As specified in the abstract, the "paper presents a survey on methods that use digital image processing techniques to detect, quantify, and classify plant diseases from digital images in the visible spectrum" (p. 1). In other words, the paper reviews digital imaging processing methods that had been tried by other researchers to address plant pathological problems. In the interview, Wanda vividly recalled the excitement said paper sparked in Kosmo:

> "He was like: It's crazy what you can do with machine learning. Look at this paper. Every disease has a different pattern and if we could do that, that would be pretty amazing."

By "if we could do that" Kosmo was referring to the development of image processing algorithms capable of classifying plant damages based on digital images of their symptoms. Furthermore, Wanda and Kosmo went on to envision, to make these algorithms accessible to farmers, they should be deployed in an app. Hence, Barbedo's paper had helped the two PhD students translate the complex problem of plant pathology into a more delineated classification problem to which one could develop a computable solution.

1.2.3. Gathering a team

The third step in assembling PHYTØ consisted of gathering a team to actually build the technological solution that Wanda and Kosmo had in mind. To do this, upon their return to Germany, the two PhD students summed up the problem they had identified and the solution they were aiming for in a PowerPoint presentation. Afterwards, they pitched this presentation to selected friends and acquaintances in order to recruit them for their project.

First, they held the presentation in front of two other PhD students who had also been involved in the research project in Brazil. One of them was Zoë, who was pursuing a PhD in social anthropology. The other was Kaspar, who was pursuing a PhD in Latin American studies. In an interview, Kaspar vividly recalled how Wanda and Kosmo visited his apartment to convince Zoë and him to take part in their project.

> "A few weeks later they entered my kitchen […] and said: 'Hey listen up. Don't laugh at us, but we had this idea during our honeymoon. Would you be up for it? Do you think it's a good idea or not? And are you in? The main thing was: We could use image recognition to make the diagnosis and then use knowledge that is available […] to do this matchmaking between: 'this is the problem' and 'this is the information' that you need to solve it. Well, I thought it was great, and said: I'm in."

As this anecdote illustrates, the presentation served its purpose with respect to Kaspar, and the same was true for Zoë, who also joined the team.

Second, Wanda and Kosmo presented their idea to three friends and acquaintances they knew, among others, through an NGO that they had helped establish during their studies. The NGO's website, which still exists today, describes its mission as developing "self-sufficient," "decentralized," and "as simple as possible" technical solutions for the fields of water conservation, agriculture, and energy. As examples of such solutions, the website provides descriptions and photos of low-tech wind turbines, water pumps made from bicycle parts, or solar powered water desalinators. The first person from the NGO network to join the new team was Friedrich, who had been in charge of the NGO's finances. The second person was Lilly, who was doing a postgraduate degree in development cooperation at the time. The last person to join the team was Titus who had studied geography with Wanda and Kosmo and who was supposed to take care of the incoming image data needed to create the image processing algorithms to be deployed in the app—a vital task in the subsequent development of the technology that the team had in mind.

1.2.4. Collecting pictures

The fourth step in assembling the PHYTØ app consisted of collecting enough images of crops and plant damages to code an initial set of image-processing algorithms that could be deployed in an app. In order to do this, Wanda, Kosmo, and the rest of their team released a preliminary app (without an automated diagnostic function), which was intended as a device to "crowdsource" the required pictures among amateur gardeners in Germany. The name of that preliminary app was "DatenGarten" (English: data garden). In an interview with Friedrich which was published on a German garden blog in 2015, he described the project as follows:

“DatenGarten is a crowdsourcing science project: Anyone can participate and support our scientific work through their knowledge. The resulting distribution maps will show the most common plant diseases in the individual regions of Germany. Nothing like this has ever been done before!” (my translation).

As this quote indicates, since the preliminary app was not yet able to automatically diagnose plant damages, the DatenGarten team had to come up with another incentive to get amateur gardeners to upload pictures of their diseased plants. As Friedrich explained, at the time, this incentive consisted of so-called “distribution maps,” that is, digital maps, indicating where in Germany plant damages were occurring on what kinds of crops (see Figure 1). To create these distribution maps, the photos uploaded by DatenGarten users were diagnosed by human specialists (initially primarily Titus), and, as soon as a clear diagnosis was obtained, incorporated into the maps.

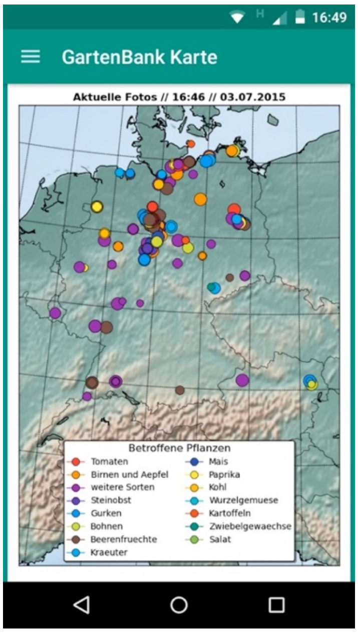

Figure 1: Distribution map (Source: Screenshot of a promotional video)

As the figure shows, there were still plenty of gaps on the team’s distribution maps. This was of course not because there were no plant damages occurring in the respective regions of Germany, but because DatenGarten did not yet have any users in these regions. Hence, in order to attract more such users, the developers of DatenGarten also relied on offline activities such as distributing flyers. In particular, they focused on allotment gardeners at the time, whom they had identified as a potential target group for their app. In an interview with Lilly, she explained how these interactions played out for Kaspar and her:

> “We just put together a cheap flyer. We printed it out somewhere super low budget and went to the allotment gardens and did- well, I definitely did that. When I saw people, I gave them a flyer just like that. At that time there was nothing going on with the image recognition, we just wanted to build this dataset.”

These interactions with amateur gardeners not only “crowdsourced” a first number of images they also changed how the DatenGarten team envisioned the technical solution they were developing in those days. As Titus explained in an interview, when Zoë and he were trying to enroll new DatenGarten users in the allotment gardens around Hanover, their experience was that the people they talked to were only mildly interested in distribution maps. Instead, as he recalled, they were much more enthusiastic about the idea of a digital “compendium” or “encyclopedia” concerned with plant damages:

> “Zoë and I went through the allotment gardens and asked people: ‘What would you like to have, a distribution map? Or would you like to have some kind of compendium on your smartphone, which would contain all the plant diseases? And everyone actually said: Of course, if there were a plant disease in the vicinity, I would like to know about it. But it would be really cool to read something about it right here. Otherwise, I have to go home to google it. That would be crappy. If I had this here on my smartphone it would be cooler.’ And then we just took this information to the others and said: ‘Actually it would be quite good if we would give them an encyclopedia now.’”

As a consequence of the described interaction with a partially satisfied amateur gardener, the DatenGarten team began to work on a feature they called “Encyclopedia.” The work on this feature was relatively straight forward and consisted of collecting information on plant damages and treatments from various sources in a Google Docs document. In a next step, this condensed information was made available in the DatenGarten app.

As a TV report from 2015 documents, in composing this content the DatenGarten team initially placed great emphasis on non-chemical treatments: The report features three amateur gardeners who are jointly testing DatenGarten in a small kitchen garden. Accompanied by the camera, the three gardeners discover that one of their zucchini plants is infested with an unknown pest. With the help of information provided by DatenGarten, they arrive at the diagnosis that the zucchini is infested by spider mites. Once this diagnosis is established, one of the gardeners goes on to read out the “biological tip” that the app recommends as a treatment, namely that they should apply “garlic tea.” Subsequently, the voice of the narrator of the report steps in to clarify the advantages of this treatment: “Most of what you need can be found in every household. In no time at all, Sina [the gardener] has a remedy ready to chase the troublemakers away from the zucchini. Very important, without chemicals!"

Despite such media attention or the face-to-face interactions described above, the DatenGarten team eventually had to realize that they were not able to crowdsource the quantity and quality of images they needed to produce the image processing algorithms they had in mind. This is not to say that the interactions with initial users that occurred during this time did not shape DatenGarten in a lasting way. Rather, it meant that the DatenGarten team had to come up with a method other than crowdsourcing to gather the data it needed to develop its algorithms.

1.2.5. Training algorithms

The fifth step in assembling PHYTØ consisted of creating a set of image processing algorithms capable of classifying pictures of a small selection of plant damages. However, in order to finalize these algorithms, the team had to change its approach to data collection. As described, among others, by Jaton (2017, 2021), who conducted detailed ethnographic research on the construction of image processing algorithms, in order to create an algorithm capable of classifying images, developers need a comprehensive "reference database." More specifically, this database ought to contain images of the objects to be classified, taken under different conditions (light, saturation, distance, etc.), so that the algorithm can "learn" the visual patterns of a given type of object in different situations. Hence, after the members of the FLORA team had spent some time trying to crowdsource the images they needed to "train" the algorithms they had in mind, they realized that the images they received "organically," that is, from users, were too few. As a consequence, they developed a different approach that consisted of producing diseased plants themselves, in a greenhouse, in order to take as many pictures of them as they needed. In an interview with Titus, he recalled this realization as follows:

> "We had the allotment gardeners of whom we took care. Then we thought. Okay, there's more to it than that and collecting pictures, just through the users, is good, but we don't get the numbers we need, we need a lot more, and then we made this greenhouse trial."

In the narratives of the DatenGarten team, said "greenhouse trial" is a frequent reference point. The greenhouse in question was an experimental greenhouse at the university of Wanda, Kosmo, Titus, and Friedrich, for which the team had been granted access to realize their project. Similarly, the team used servers provided by the university, which formed the first information infrastructure of the project. In an interview, Kosmo summed up the experimental set up of this trial in a concise manner.

> "Titus and I went to the plant nursery and bought 150 tomato plants, put them in the greenhouses of the university, did nutrient experiments, collected photos, trained the first machine learning algorithms."

Beyond this brief description, Kaspar provided a bit more detail on the actual setup of the "nutrient experiments" that Titus and Kosmo conducted:

> "They bought self-mixing fertilizer, from the garden supply store: One bottle of liquid iron, one of liquid phosphorus, one of liquid nitrogen, to mix the fertilizer for themselves. Then they used that to artificially supply one hundred tomato plants that they had set up at the university with nutrient deficiencies: the first row of thirty plants got an iron deficiency, the next one got a nitrogen deficiency, the next one a potassium deficiency and so on. And while they [the plants] were experiencing these deficiency symptoms, they [Kosmo and Titus] collected photos the whole time to see if the idea would work."

Hence, for their nutrient experiments the DatenGarten team opted for one kind of crop which they could access easily (tomatoes), and one type of plant damage which they could induce themselves in a controlled manner (nutrient deficiencies). This experimental set up finally enabled the DatenGarten team to produce the quantity and quality of pictures they needed to develop functional image processing algorithms for the classification of nutrient deficiencies in tomatoes that could be deployed in the app. The FLORA team usually refers to this technological achievement as PHYTØ's "proof of concept," which can be explained by the fact that it ushered in the next phase in the app's assetization process.

1.3. Selecting funding sources

The second phase in the process of turning PHYTØ into an asset revolved around the problem of selecting funding sources to finance the future development of the app. This phase extended from the moment the FLORA team received a spin-off scholarship from the German state (2015) to the moment the team raised its first round of venture capital (2016). Besides the new partnerships that FLORA forged during this phase, PHYTØ's diagnostic capacity also continued to improve.

1.3.1. Becoming a spin-off

The PHYTØ team's search for funding began with and was greatly facilitated by a one-year scholarship by the German state aimed at turning university projects into academic spin-offs. As the program's website puts it, the goal of the scholarship is to increase "the number and success of technology-oriented and knowledge-based start-ups" (my translation). As Kaspar explained in an interview, the fact that his team had an app equipped with a set of functional image processing algorithms by the time they applied for the scholarship figured greatly in their application:

> "The proof of concept, that was basically: 'If we have enough pictures with the right label on them—for example this picture shows a tomato with an iron deficiency—does it work? Yes, it does.' That was the proof of concept. Then we said: 'Cool it works.' And with that we went to the scholarship program: 'The proof of concept is done, this and that could be the different fields where it is useful.'"

Since the scholarship program the DatenGarten team was aiming for explicitly aims to increase the number and success of startups from German universities, the application process already revolves around building a network of partners to assist applicants in implementing their idea, both from a scientific and from a business point of view. As further stated on the website of the scholarship program, to be eligible for funding, applicants must complete a number of tasks. Among other things, they must submit their "business idea in the form of an idea paper" (my translation). Additionally, applicants are required to name a "mentor" from their research institution who "takes over the technical and professional supervision of the founding preparation." On top of that, applicants are assigned a "coach" who "accompanies them in the entrepreneurial preparations for founding a company and the preparation of a business plan." As Kosmo's next quote shows, in the case of his team, the gathering of these partners served its purpose in that it introduced the developers of PHYTØ to the world of startups—a world to which they had little previous exposure:

> "Then we looked for consultants within the university. One of them was our professor, who was our mentor anyway, and then we got someone else for the business side. I forgot the name of the lady, but she did economics. So, she knew a lot about startups because we didn't know anything about business. And that's how this whole topic of startup and venture capital approached us."

The team's application was successful, and they received the grant for a one-year period between 2015 and 2016. This achievement was accompanied by important formal changes: On the one hand, in June 2015, "DatenGarten" was officially rebranded as "PHYTØ," to appeal to a more international audience. On the other hand, in November 2015, the team legally founded the startup FLORA.

Besides monetary support, the spin-off scholarship provided the FLORA team with non-monetary support. This non-monetary support consisted of coaching sessions, accompanying seminars, evaluations of interim presentations, and feedback on an initial business plan. The latter document gives a vivid insight into how the FLORA team envisioned the commercialization of PHYTØ at the time. More precisely, the business plan outlines a multitude of ways of how the app could be monetized. First, it mentions in-app purchases of analytical services like personalized weather and soil data. Second, the document describes that PHYTØ could establish links to commercial platforms selling gardening supplies. Third, the business plan proposes to rent out access to FLORA's image algorithms to other smaller app providers, manufacturers of pesticides or other inputs, and large agricultural machinery companies. Lastly, the document outlines the sale of metadata generated via PHYTØ to support market analyses of agricultural insurance companies, and, again, manufacturers of pesticides or other inputs. Although the commercialization strategies outlined in the business plan were still largely hypothetical when the document was written, they would have a noticeable influence on the trajectory of FLORA in the years to come.

Besides the business plan, another important device that emerged from the scholarship was FLORA's first "pitch deck," that is, a concise PowerPoint presentation that summed up why potential partners should collaborate with or invest in the startup. In an interview, Kaspar summarized the necessity that they saw in the pitch decks at the time:

> "And then, practically at the end of the scholarship program, we already screwed together our pitch deck and said, okay, that's the message we're going to push. That's what we want. We're going to do fundraising somehow. We already knew that we had to get money somehow, otherwise it would die."

To summarize, the scholarship served three important functions in FLORA's search for funding. First, it provided the team with money to fund the ongoing work on PHYTØ and the search for future funding sources. Second, it embedded the FLORA team in a small network of specialists who helped them turn their project into a company. Third, it yielded two other objects that, much like the app itself, should help pique the interest of prospective business partners and investors, namely a business plan and a pitch deck. As Doganova and Eyquem-Renault (2009) have shown, material devices like pitch decks or business plans that express and circulate the business model of a given company often act as "boundary objects" (Star & Griesemer, 1989) as they facilitate cooperation between the company and other social worlds. As the next subsections will show, this argument neatly applies to the case of FLORA.

1.3.2. Partnering with agrochemical corporations

A second important step in FLORA's search for funding was to negotiate and eventually enter into business partnerships with agrochemical groups. According to the co-founders of the startup, due to their background in alternative agriculture and low-tech communities, they were initially rather skeptical to cooperate with said companies. As the FLORA team recounts it today, the contact occurred rather coincidentally and was initiated by the agrochemical companies themselves. To fully understand the initiation of the cooperation between FLORA and these Big Ag corporations, one must begin by explaining a particular practice that the FLORA team developed at the time of the spin-off scholarship and still relies upon today—a practice that they refer to as "picture hunting."

In a nutshell, the term picture hunting denotes the act of sending people with plant pathological expertise to selected fields to track down and photograph plant damages that are lacking from FLORA's database. In an interview, Titus recalled the reasoning that led the PHYTØ developers to this approach:

> "The greenhouse trial was working, now we just had to get more pictures. And we could only find them in the field. We didn't just want to have pictures from allotment gardeners. We wanted to have agricultural pictures of wheat and other things."

In other words, the FLORA team faced the problem that their previous methods for collecting images ("crowdsourcing," "greenhouse trials") generated not enough images of agriculturally relevant crops and plant damages. As a consequence, the FLORA team began to selectively search or respectively "hunt" for these images in the field. More specifically, they focused on the fields of public agricultural experiment stations as operated in various German federal states. The reason for this was that one of the functions of these experiment stations is to conduct plant pathological surveys on a regular basis to determine which plant damages pose a particular risk in a given year. One method by which the experiment stations do these surveys are randomized controlled trials in which the station's staff treats different experimental fields to varying degrees with common crop protection products before comparing the plant pathological problems occurring in those fields to untreated control fields. In agreement with the stations, FLORA used this experimental setup for its own purposes, by sending its picture hunters to the fields to take pictures of the occurring plant damages. Through this approach, FLORA's image database grew steadily, especially with regard to agriculturally relevant crops and their common diseases. As a concomitant effect of this growing image database, FLORA's software engineers succeeded in developing an increasing number of algorithms to automatically classify the respective crops and diseases.

When the practice of picture hunting was relatively routinized, and PHYTØ was able to classify an increasing number of plant damages, a first agrochemical corporation became aware of FLORA and contacted the startup in a rather unconventional fashion. As Kosmo recounted in an interview, one day FLORA received numerous pictures of plant damages that had apparently not been taken in the field but photographed from a printed document. All of these images, Kosmo continued, had a small logo of a large German agrochemical company on them. This prompted Kosmo and his team to check the geo-coordinates of the user who had uploaded them, whereupon they discovered that the images had been uploaded from the headquarters of said company. Subsequently, one of FLORA's investors put the startup in touch with the company, using the fact that it had already "played around" with PHYTØ as a basis for negotiation.

The result of these negotiations was that FLORA began developing algorithms on demand, that is, for the classification of plant damages that the agrochemical company deemed important for its own customers. The startup then rented out access to these selected algorithms to the agrochemical company which in turn deployed them in its own company-branded app. In an interview one of FLORA's first "picture hunters" recalled the beginnings of this business partnership:

> "It all started with searching for wheat diseases in the field, when I was still in [city], part-time. And the data was used to feed the B2B networks with which [agrochemical company], for example, makes queries with its own app. They are still used today."

Another interesting aspect of this partnership was that FLORA initially rented out its algorithms in a "white-labeled" manner, that is, without granting the agrochemical company the right to disclose that the algorithms it was renting had been developed by FLORA, again reflecting a certain reluctance of being associated with the agrochemical industry. In an interview, Titus explained this procedure stating that the business partnership with the agrochemical company initially was not so much about extracting revenue as it was about preventing the company from attempting to copy FLORA's technology.

> "We have pondered: 'Hey, do we really want to do this [cooperating with agrochemical companies]? So, the gamble was that if we gave them the technology, they wouldn't work on something like this themselves. That would give us a little more peace and quiet."

The portrayal of the relationship between FLORA and the agrochemical company in the preceding quotes reflects the classic argument of sociologists of innovation that, "[t]o adopt an innovation is to adapt it" (Akrich et al., 2002). In other words, by adopting some of PHYTØ's algorithms, the agrochemical company has simultaneously begun to align the app, and its developers, with some of its corporate interests. In this specific case, the alignment was to define some of the next crops and plant damages for the recognition of which FLORA would develop new algorithms—a work that will be discussed in more detail in chapter two. In the next quote, in which Titus explains how the agrochemical company began to "test" FLORA, the influence that this new business partner began to exert on the startup becomes even more apparent:

> "They just caused us a lot of stress because they tested us. They just said: 'We want to have these and those diseases.' And we said: 'Yes, okay, we'll do that for you. We don't have them on the list yet, but we have the resources to send people out and include these plant diseases.'"

Simply put, one could say that both companies benefited from the cooperation, whereas it appeared that FLORA was more dependent on the agrochemical company than the other way around—a condition which the new business partner leveraged by placing high demands on the startup. Put another way, one could say that the above descriptions illustrate how the cooperation between the agrochemical company and FLORA led to a two-way transformation. With regard to the agrochemical company, the cooperation equipped the corporation with a new diagnostic technology to increase the sale of its own products. With regard to FLORA, the cooperation resulted in the startup's first revenue stream, and shaped the ensemble of crops and plant damages that were included in PHYTØ's diagnostic repertoire. In the years that followed, other renowned agrochemical companies would also begin to rent access to FLORA's algorithms, resulting in an initial revenue stream. However, it was already apparent at that time that renting out access to PHYTØ's algorithms would not be enough to constitute a full-fledged business model capable of sustaining the company in the long term, which is why the team kept an eye out for further sources of funding, one of them being a public-private partnership (PPP).

1.3.3. Negotiating a public-private partnership

The third important step in FLORA's quest for funding was the negotiation of a public-private partnership with the "Deutsche Gesellschaft für Internationale Zusammenarbeit" (GIZ, English: "German Corporation for International Cooperation"), Germany's most influential development agency. The contact with GIZ had been initiated by Lilly, who had begun working as a consultant for the development agency in parallel to the early formation of FLORA, when it was not yet clear whether the startup would survive. A typical career path for GIZ consultants starts with an induction period in Germany followed by a longer assignment abroad. In Lilly's case, this assignment took place in Mali.

In our conversation Wanda recalled that Lilly's boss at the GIZ was delighted with PHYTØ. As she put it, "he thought it was super cool and said: I want this in Mali." The FLORA team was equally enthusiastic about the idea of cooperating with GIZ and agreed to joint negotiations. However, as Wanda pointed out in the further course of the interview, these negotiations revealed rather quickly that there were some disagreements between GIZ and FLORA that were difficult to resolve. The first of these disagreements revolved around the formal requirements that the GIZ placed on potential private partner organizations. Simply put, FLORA was too small and too young a partner for the GIZ. Wanda explained this situation as follows:

> "It took us an infinite amount of time because we simply did not meet certain criteria. Normally you must have done a project, with a minimum value of 500.000 Euro in the past, as a private sector entity. You have to have a minimum annual turnover of 1 million euros, and you have to exist for this and that amount of time, and so on and so forth."

However, as Wanda went on to explain, at some point, "after a long struggle" the FLORA team, with ample support from Lilly's boss, managed to convince the responsible GIZ staff to make an exception in their case. As a result, the GIZ published a call for projects that was "tailored to" PHYTØ. Unfortunately, when the project call was announced, GIZ and FLORA were again in disagreement. This time the disagreement revolved around the question of whose product PHYTØ would be once it was made available in Mali. Wanda described this discrepancy in the following words:

> "We had a long discussion about the fact that we wouldn't white-label PHYTØ for them and that we wouldn't sell them PHYTØ for Mali. But that instead, this would still be our product and we would of course continue to maintain it over the three years that the project would go on."

Hence, unlike in the case of the agrochemical industry, FLORA wanted to be publicly associated with the GIZ rather than selling PHYTØ as a white-labeled product to the development agency. In a similar vein, another disagreement with GIZ centered on who would own the data Malian farmers would generate once they would begin to take and upload photos with PHYTØ. As Wanda clarified, the GIZ "wanted exclusivity on the data," to which FLORA responded, "No way! We are more than willing to share them, but only you getting the data is out of the question." Another disagreement concerned the costs that the FLORA team estimated for its work in Mali, which Wanda summed up as follows:

> "We made an estimate, which was that we definitely need two people, international people, on the ground. I don't know exactly what we estimated, something like 1.2 million, or so, for three years. And then they said: No way, you have to do it for 700.000. You have to cut out at least one international position. And then we said—in the meantime we were much, much further. You can imagine that three years in the process, from the very beginning, we developed quite drastically. We don't really want Mali at all. Mali is completely lost. We don't even have connectivity and all that."

Hence, in addition to the disagreements mentioned so far, this quote illustrates that the FLORA teams' gradual detachment from the PPP in Mali had another important reason that could be described as infrastructural. This reason was that the mobile internet ("connectivity") in Mali was worse than the FLORA team had imagined, making it difficult for users to upload images of the required quality from the field. This circumstance greatly dampened the founders' initial enthusiasm to promote PHYTØ via a PPP in Mali.

Taken together, these descriptions of the negotiations with GIZ illustrate how FLORA gradually distanced itself from the initial idea of cooperating with the development agency in Mali, and eventually abandoned it altogether. However, despite all the disagreements with the GIZ, the termination of the planned PPP in Mali did not burn all the bridges between FLORA and the development agency. Several months later than the attempted PPP in Mali, the GIZ and FLORA launched a different PPP in a North African country. Nevertheless, the negotiations with GIZ had made it clear to the FLORA team that the development agency too was not a suitable source of long-term funding for PHYTØ, thus, gradually increasing the appeal of the world of venture capital.

1.3.4. Raising venture capital

The fourth and arguably most formative step in FLORA's search for funding consisted of various encounters with the world of venture capital, which eventually led to FLORA raising a first round of venture capital itself. As Kosmo portrayed it in an interview, FLORA's increased focus on venture capital was closely related to an entrepreneurship award they won in March 2016. The prize was awarded by a municipal bank from her university town and a local business development agency, and included a trip to Silicon Valley for two people organized by an association of German startups. From FLORA's side Kosmo and Friedrich were to participate in the trip. As the former recalled in an interview, the journey to Silicon Valley fundamentally changed their conception of venture capital:

> "We went to Silicon Valley with the startup association and there we understood venture capital for the first time. Because among us were a few start-ups that were just further ahead than we had been, that already had angel investments and so on, and they just happened to have a better idea about it. [...] Anyway, we understood that our idea of venture capital was naïve, that the way we pitched it was far too naïve, that we were far too scientific."

The important aspect about this quote is that it illustrates how the exposure to other startups, stories of angel investors, and explanations of venture capital, began to weaken the ties between FLORA and other social worlds that had previously been important to the team of the startup—in this case indicated by statements like "our idea of venture capital was naïve" or "we were far too scientific." In the words of Callon's (1984) sociology of translation, one could say that FLORA gradually became "interested" by different actors affiliated with the world of venture capital. Consistent with this interpretation, Kosmo went on to emphasize, that the trip to Silicon Valley and the contacts they made in the course of it opened them the doors to Germany's startup scene. As he explained it, not long after the trip, Wanda and himself began to commute the 258 kilometers between their university town and a major German city with a lively startup culture on a regular basis to "stroll through the early-bird, seed-stage scene" and to "pitch" the story of PHYTØ to "two or three people per trip."

One of these people happened to be Giorgio, founding partner and CEO of a local "early-stage venture capital investment firm." As Kosmo put it, FLORA's "pitch-deck" was anything but refined at the time. Nonetheless, it somehow caught the attention of the venture capitalist in question:

> "One of these folks was from [venture capital firm], Giorgio. He almost immediately- We were there the first time; we talked to him. We were there the second time; we talked to him. We had such a bad pitch-deck, it was totally black and looked like crap, with way too many ideas in it and way too few concrete ones. And the second time he said: Yes, he thinks it's cool, he would do it. And we thought the same way. We were like: Yes, he is definitely a cool freak, and he sees a rough vision in it."

As is usual, after the meetings with the venture capitalist, it still took some time for the parties involved to finalize the deal. One important subject of the conversations leading up to the final deal was the location of FLORA's office. In an interview, Kosmo explained that although it was not a mandatory requirement, the venture capitalists suggested to the developers of PHYTØ that they move their headquarters from their university town to the major German city that was home to the offices of the venture capital firm, which operated its own startup incubator there:

> "At some point Giorgio just said: 'Well, we'll do that, and I think it's cool. I have only one question in the end: Do you want to stay in [university town]?' And we were just like: 'Yes, we definitely want to stay in [university town] we have a great network here and everything is great and so on.' And then he said: 'Well, then, please tell me one thing: How do you bring talent to [university town]?"

The co-founders of FLORA had no answer to this question, so they followed Giorgio's recommendation and moved the startup's headquarters to the premises of the venture capital firm. About the same time, in December 2016, the business platform "Crunchbase" announced that FLORA had closed a seed financing of 1.1 million Euro with the aforementioned venture capital firm as lead investor. This first round of venture capital funding and the physical relocation of FLORA's office to the premises of the venture capital firm's incubator ultimately ushered in the next phase in the process of turning PHYTØ into an asset—a phase in which both FLORA and PHYTØ had to undergo quite radical transformations to attract further rounds of venture capital funding.

1.4. Increasing user numbers

The third phase in the assetization of PHYTØ revolved around the problem of increasing the number of PHYTØ users—a goal that was increasingly called for by the venture capitalists who invested in FLORA. This phase spanned from the moment in which FLORA raised its first round of venture capital funding (December 2016) to the moment when FLORA raised its third round of venture capital funding (January 2018). The most important transformation FLORA and PHYTØ underwent during this period was a sharp refocusing on India as target region. This refocusing was accompanied by important changes in the organizational structure of FLORA, its collective, and its technology PHYTØ.

1.4.1. Turning to India

As indicated above, the first step in FLORA's efforts to increase the number of PHYTØ users was to focus the app on a single country. More specifically, while the FLORA team initially tried to "roll out" PHYTØ in multiple countries at once, as of early 2016, the startup began to focus its efforts on India. The co-founders of FLORA attribute this shift in their startup's strategy to an incident that occurred during a conference on innovation in rural development hosted by the GIZ and attended by both Wanda and Kosmo. In an interview Kosmo described this incident at length. What is important about his account is that it illustrates how the FLORA team—much as it did with regard to the problem of funding—weighed different countries against each other before finally settling on India:

> "We were at a conference in Feldafing, from the GIZ, where we had an Indian guest speaker who came from [a private provider of an agriculture app]. He gave a lecture. And we had written this proposal beforehand about how many farmers we could reach in Mali, and we calculated that we would reach about 10,000 farmers by the end of the [GIZ] project. And then the guest speaker just said: '…and then we call the people who use our app twice a year.' And then somebody asked: 'How many users do you have right now?' Then he said: '600,000.' Then someone else said: 'That's 1.2 million phone calls you have to do.' And then someone sat next to me and said: 'Yes, yes, India brings the numbers.' In that moment, it just kind of clicked for me and I thought: "Well, that is impressive, Mali has 20 million inhabitants, which is less than the population of any state in India. […]. So of course, you have a language thing, but I mean we talked about translating PHYTØ to Bambara [national language of Mali]. You know? And I don't know, Bambara is spoken by two million people. And then I started looking at the Indian languages. [...] And then I started thinking about it and I was like, 'That's pretty awesome. Marathi, 110 million people. Telugu, 19 million people. Hindi, 550 million people. All small farmers."

As this quote shows, India had two advantages over Mali—and other countries in which FLORA had made the PHYTØ app available for download—with respect to the problem of user acquisition. For one thing, India has a much greater population. For another, it has large contiguous language areas. According to the FLORA team's gradually evolving plan, these conditions would allow to make PHYTØ available to a broad user base relatively quickly and relatively cost-effectively using targeted translations of the app's content into widely spoken languages. Besides population and language, two other aspects of infrastructural nature spoke in favor of India. In the interview, Kosmo summarized these aspects as follows.

> "And then the connectivity thing came on top of that, too. And we were like, it's true, it is much more advanced. It is cheaper. It's better developed, and it has many more farmers. Is it really a clever idea to start PHYTØ in Sub-Saharan Africa now? Because we just wanted to have an impact on small farmers, that's what we wanted to do all along."

As indicated by Kosmo, the mobile network in India at the time was far better developed than the mobile network in Sub-Saharan Africa. In addition, mobile data was relatively cheap there compared with most African countries. Besides these factors, as the next subsection will elaborate in further depth, India's institutional landscape of agricultural research also played a non-negligible role in PHYTØ's increasing foray into India.

1.4.2. Opening a regional office

The second important step in FLORA's efforts to increase the number of PHYTØ users was the opening of a regional office in the premises of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) near the Indian city of Hyderabad. In brief, ICRISAT is an international organization, that conducts research for rural development purposes. Since its inception in 1972, the organization has been an integral part of the world of agricultural research and extension in India and beyond.

As many of the partnerships that FLORA has forged over the years, the collaboration with ICRISAT was not necessarily planned, but arose as a concomitant of other activities. Towards the end of 2015, that is, over New Year's Eve, Wanda and Kosmo visited Lilly, who at that time was still working as a consultant for GIZ in Bamako. As chance would have it, Bamako is not only home to a GIZ office, but also to a regional office of ICRISAT. So it happened that the developers of PHYTØ met the head of the local ICRISAT office at a New Year's Eve party. As Kosmo recounted in an interview, the ICRISAT representative showed great interest in the app and offered to establish contact with the organization's headquarters in India. The FLORA team readily accepted his offer and just a few months later, in August 2016, the startup's Facebook page announced the first India journey undertaken by two of its co-founders, Zoë and Titus.

To increase the number of PHYTØ users in India, the FLORA team had defined a clear goal for Titus and Zoë's stay. As with the expansion of PHYTØ in Germany, the startup initially aimed to build an image database of local crops and plant damages, which should serve as a basis to develop image recognition algorithms that would benefit Indian users. Unlike in Germany, however, in India this work should be carried out primarily by partner organizations among which ICRISAT played a central role. In an interview I conducted with Titus, he explained in more detail the work that ICRISAT personnel were supposed to perform in FLORA's early days in India.

> "The first goal for us was to get in touch with partners who would actually collect data for us. Basically, the thing was always, how do we get labelled pictures as fast as possible, because we didn't have that many users in India yet. So how do we get the extension managers or any experts to collect images for us."

By "labeled" images, Titus was referring to images that are equipped with a digital name tag of the crop as well as the plant damage depicted. As will be discussed in more detail in the following chapter, these labels are an essential prerequisite for training functional image recognition algorithms. For now, it should suffice to say that, as in Germany, plant pathological expertise was needed to build up the image database that FLORA required for its expansion in India. Again, a certain amount of time should elapse between the first contact of FLORA and ICRISAT and the formalization of an official partnership. However, once this partnership was settled, ICRISAT became the primary mediator in providing FLORA with agricultural expertise adapted to India.

In the initiation of the partnership between FLORA and ICRISAT, once again, a startup incubator played an important role. More specifically, in February 2017, a specialized incubator for startups concerned with agriculture and rural development issues was scheduled to open on ICRISAT's premises. Hence, FLORA came into contact with ICRISAT at an opportune moment. As Titus explained during an interview, while the director general of ICRISAT at the time was rather reserved with respect to PHYTØ, it was primarily the head of the startup incubator who pushed for a longer-lasting cooperation between ICRISAT and FLORA, as he was looking for startups to inhabit his incubator:

> "That was the first year he got this job as head of this IT department of ICRISAT, and he just started looking for startups, so it was a great timing, because [the director general] might have invited us but starting something bigger with him wouldn't have happened. He didn't really know what to do with us. But because they just opened up this new IT branch, it fitted in really well. And then we always went there and organized everything from there."

Together with the workplace at ICRISAT, FLORA recruited some of the scientists working for ICRISAT for a limited period of time. More specifically, FLORA hired a senior scientist named Kumar and two PhD students, all of whom had backgrounds in agricultural technology, biology, or plant pathology. So, by February 2017, FLORA had its first regional office in India including staff who were well-versed in the country's agrifood systems—a factor that should soon cause the number of PHYTØ users to increase rapidly.

1.4.3. Modernizing extension

The third step in FLORA's efforts to increase the number of PHYTØ users was to position PHYTØ as a tool to modernize India's extension sector. One employee of FLORA who played a key role in this process was Kumar.

One central argument the scientist advanced to position PHYTØ as a tool to modernize India's extension sector was that there was a shortage of agricultural extension services in rural India, which PHYTØ might be able to bridge. As he put it in an interview,

> "the problem is that farmers are not getting the type of information that they need because they can't rely- People are not available, extension workers, to the farmers. So, this [PHYTØ] becomes like an independent validating tool.

In other words, the argument that Kumar and his team put forward in trying to anchor PHYTØ in India's extension sector was that farmers were lacking "reliable" or "independent" advice—an argument that is consistent with debates of other agronomists and extension scientists concerned with India's extension sector.[23] In other words, Kumar presented PHYTØ as an independent or objective tool to improve India's extension sector. To further advance this point, he began to "train" agricultural extension agents and students at agricultural universities, in using PHYTØ. By his own account, between 2016 and 2018, Kumar taught approximately 15,000 agricultural advisors and prospective agricultural advisors in the use of the app. In other words, Kumar executed the work of finding agricultural experts capable of adapting FLORA's image database to the local specificities of Indian agriculture, for which Titus and Zoë had originally come to India. To be clear: The extension agents and students that were instructed by Kumar were not paid for their use of PHYTØ. Rather, the app was presented as a tool to complement their plant pathological expertise, or as Kumar presented it above, as an "independent validating tool."

The approach taken by Kumar and his team achieved the goal of considerably increasing the number of PHYTØ users, which was rewarded by venture capitalists. More precisely, in April 2017, about six months after Titus and Zoë had first traveled to India, the website Crunchbase reported that FLORA had successfully raised a second round of venture capital. The investors

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[23] Glendenning, C. J., Babu, S. C., & Asenso-Okyere, K. (2010). *Review of agricultural extension in India: Are farmers' information needs being met?* IFPRI discussion paper. https://www.ifpri.org/publication/review-agricultural-extension-india

in this round were an angel investor from Germany and again the venture capital company from FLORA's first financing round. Unlike the first round, the amount of money raised in this second round was not publicly disclosed. Aside from that, not much changed in terms of the VCs' originally articulated goal of increasing the number of PHYTØ users in India. A quote from an interview with Kosmo, in which he reconstructed the pitch with which they had raised the first round of funding and the one with which they raised the second round of funding, illustrates this point nicely:

> "Our pitch to Giorgio, a year before, was: 'We can do that. This works. We tried this once in Germany, now we're taking this to the world.' And the pitch next year was, 'Look we did this in Telangana [Indian state in which ICRISAT is located]. Here you can see the traction we can build. It's slowly working in the Hindi belt but that can be scaled to the whole- that can be scaled much, much further. We can add many, many more languages to it and just add many more plants to it.'"

Hence, the pitch FLORA used to raise the second round of funding was that PHYTØ's user base could be increased much further by translating the app's content into other languages spoken in India and by adding additional crops and plant damages.

In this further increase of the number of PHYTØ users, too, Kumar played a decisive role. This was due to Kumar's ongoing efforts to win over policy makers as advocates for the PHYTØ app. Since Kumar himself had worked for the local government before joining ICRISAT, he managed to arrange several meetings with representatives of the agricultural administration of a major Indian federal state. As he described it in our interview, to convince these representatives, he used a particular method, which consisted of demonstrating the use of PHYTØ, based on printouts of plant damages that he brought to the meetings:

> "What we used to do, the demonstrations that we used to do, basically, via printouts of symptoms, and then we'd show them. Sometimes there were glitches but independent of that it was working well. Then, you know, the curiosity, like: 'Okay it shows an answer, so it does work, okay.'"

Meetings with government officials were not the only situations in which Kumar used this technique to get people interested in PHYTØ. Likewise, he used it at agricultural trade fairs to convince farmers and extension agents of the app. Situations like these underscore the suitability of PHYTØ for public demonstrations. As Rosental (2007) puts it, demonstrations are to be understood as processes "situated on the crossroads of a probationary approach […] and of ostentatious conduct" (p. 35). In other words, they work towards attracting the interest of different audiences by "mobilising the repertoires of both proof and persuasion" (Doganova & Eyquem-Renault, 2009, p. 1568). As these different accounts of Kumar's demonstrations suggest, it was primarily the fact that his audience could try out PHYTØ with their own hands, and that the app showed them immediate, unambiguous results in return, that made his interventions so successful.

As Kumar further explained, through these demonstrations and his professional network, he eventually succeeded in arranging a face-to-face meeting with the Chief Minister of the major Indian federal state, with whose administrative officials he had previously spoken. As becomes clear from the subsequent quote, during the meeting, Kumar again used the same method to demonstrate PHYTØ and ultimately succeeded in turning the Chief Minister into an advocate of the app.

> "There was a big collectors conference, where all the ministers and administrators, the collectors, the bureaucracy, everybody was there. At that time the secretary gave me time to speak to the Chief Minister directly and present. […] So, I had almost a fifteen, sixteen minutes debate, discussion with the Chief Minister. He is a very digitally savvy person I told you. So, once he was convinced and he saw the demonstration he said, 'I want to' you know, 'launch this for the people of my state and, I mean, also the country.'"

As a result, in May 2017, the Chief Minister, formally launched PHYTØ at a public political event. Also at the event was the then Director General of ICRISAT, who, together with the Chief Minister, smilingly held a tablet on which PHYTØ was opened into the cameras pointed at them. In a press statement released after the event, the Director General let it be known that the app could prove to be a "game changer" in the realm of agriculture, and that it could even "take on the role of an extension worker"—an interesting assertion that will be explored in more detail in chapter three of this dissertation. In short, everything suggested that Kumar's plan to position the app as a means to modernize India's agricultural extension sector had succeeded for now.

As Kosmo explained in an interview, this event made an important contribution to FLORA's goal of further increasing the number of PHYTØ users in India. This was because the event provided the startup with visual proof of PHYTØ's political relevance—visual proof that the startup's online marketing team could multiply across social media with relative ease:

> "There was a pretty big media event—there are photos of it and documentation—where the head of ICRISAT, the Chief Minister, and from our side Kumar were present. And that got quite a lot of media attention and we just took TV reports and scaled them on Facebook and

> spread them around and that made them bigger and that worked really well. That means that we could prove then: 'Hey guys, if we translate the whole thing into a local language and get a little bit of media publicity, then it can be spread.'"

As Kosmo went on to recount in the interview, Giorgio was pleased with the user growth that FLORA had demonstrated in India. Hence, the venture capitalist was confident that the startup should be able to raise another round of funding. Nevertheless, he also gave the FLORA team another recommendation for their upcoming pitches, which Kosmo paraphrased as follows: "Listen guys, you're a small team, you can't build three products at the same time. It's not going to work. Do one thing really well." With this recommendation, the venture capitalist was referring to the fact that FLORA had been considering many different commercialization trajectories up to that point, without committing to one. So, Giorgio advised the FLORA team to create "a nice deck" placing a more specific focus on one business model to monetize PHYTØ—a process in which the venture capitalist wanted to assist the startup. As Kosmo recounted it, this focusing consisted of leaving aside ideas like "drone surveillance" and "tractor surveillance" and concentrating on the development of an additional PHYTØ feature that was intended to "guide" small-scale farmers through the growing season.

The exact nature of this feature and the underlying business model will be discussed in the following section. For now, it should suffice to say that the venture capitalist had been right. After Wanda and Kosmo had pitched PHYTØ's recent progress in terms of user growth as well as their new story with an increased focus on guiding small-scale farmers on various occasions, they finally caught the attention of a representative of another, bigger venture capital firm with various offices in Europe and the USA. As a result, in January 2018, the website Crunchbase announced that FLORA had closed a seed stage financing of 4.5 million Euro with the newly joined venture capital firm as lead investor, which initiated the next phase in FLORA's trajectory.

1.5. Extracting revenue

The fourth and, for now, final phase in the assetization of PHYTØ eventually revolved around the problem of extracting revenue from the app. This phase began at the moment when FLORA raised its third round of venture capital funding (January 2018) and is still ongoing at the time of writing (mid 2022). The main transformations FLORA and PHYTØ went through during this phase revolved around the problem of developing a viable business model to commercialize the app. This process was divided into two steps. In a first step the FLORA team developed and implemented a business model based on selling aggregated user data, which ultimately failed. In a second step, they developed and implemented a platform business model, in which they generated revenue by charging commissions on brokered pesticide sales, which has persisted to this day.

1.5.1. Selling data products

The first step in FLORA's efforts to extract revenue from the PHYTØ app revolved around the idea of selling aggregated user data to third parties. As a technical foundation for this business model, in the months following the third funding round, the FLORA team developed a new PHYTØ feature that was called "Plant Pro."

The basic idea of this feature was to provide PHYTØ users with practical advice on how to grow their crops throughout the entire growing season. This advice was supposed to be displayed to them in small, illustrated units. As specified in an internal document used at FLORA to onboard new employees, the PHYTØ developers refer to these units as "events" and describe them as comprising "best practice tips for all management needs of users." Additionally, the document explains that "[i]n a cropping cycle from about 3 to 4 months" users should be provided with "30 to 40 events for each crop."

As FLORA regularly emphasized, the advice provided by the Plant Pro was supposed to be "customized." To deliver on that promise, the events of the Plant Pro were written and curated by agricultural specialists working in the different offices of FLORA. In addition—and this is where the business model underlying the Plant Pro came into play—when PHYTØ users began using the Plant Pro, they were asked to enter a variety of information such as the crops they were growing, the date they planted or sowed them, or the size of their land. On the one hand, these data too were collected to customize the advice given by the Plant Pro. To give just one example, the FLORA team imagined that by collecting the planting or seeding date of a given crop, PHYTØ would be able to recommend practices such as applying fertilizer or preventive chemicals at the right moment in time. On the other hand, the FLORA team planned to generate a revenue stream by selling the data collected via the Plant Pro in aggregated form to third parties (e.g., agrochemical companies, agricultural machinery manufacturers, food manufacturers, government agencies, insurance companies). More specifically, the FLORA team had the idea that the questions of the Plant Pro could be adapted to the informational needs of these different customers. To give a hypothetical example, one could imagine that a seed drill manufacturer would have contacted FLORA to ask at what row spacing most of their users were sowing a particular crop, whereupon the developers of PHYTØ would have integrated a question into the Plant Pro asking for this very information. In short, then, the envisioned business model behind the Plant Pro revolved around the idea of assembling and selling aggregated user data on demand.

In practice, however, the implementation of the Plant Pro created a number of problems. As one of the specialists responsible for the content of the Plant Pro explained in an interview, it was more difficult than expected to determine the growth stage of crops at a distance, and accordingly to display events at the appropriate point in time. In a similar vein, another specialist explained that it was difficult to accurately explain more complex agricultural practices, such as field monitoring practices as foreseen in IPM, through the interface of a mobile app. Another problem that arose was that the FLORA team found that a sizeable number of PHYTØ users were illiterate or poorly literate, or simply quickly lost interest in the advisory texts of the Plant Pro.

Ultimately, however, it was a different problem that led the FLORA team to abandon the idea of building PHYTØ's business model based on the Plant Pro. Although the software infrastructure and the content of the Plant Pro was already well advanced, until 2018, the idea that this feature could generate revenue remained a working hypothesis. In that year, Wanda and Kosmo made their way to India to pitch the Plant Pro and its associated business model to potential customers. In an interview, Kosmo recalled how this trip made them realize that the construction and sale of data products would require greater changes to the organizational structure of FLORA than originally anticipated—changes they ultimately did not want to embrace:

> "We made a presentation and developed a concept and Wanda and I travelled through India and met a lot of stakeholders. They were like big insurance companies, agricultural producers, and we just kind of mocked it, you know: This is our data product. That's what it could look like, do you have any interest in buying the whole thing? And we just found out that- you talk to ten people and ten people have ten different wishes about what should be in this data product. You know, some people wanted to know the row spacing. The others just wanted to know the amount of fertilizer. The next wanted to know whether the small farmer is in debt. The next was interested in the sowing date. And then we just said relatively late, probably last year October, November, after we came back: Okay, this is not working. We might do this data thing, but not now. And we're not going out with that to pitch it now, because that just creates too many problems."

In short, by pitching the Plant Pro to potential customers, Wanda and Kosmo came to realize that the underlying business model would not be able to sustain the startup in the long run. As Kosmo explained later in the same interview, the business model "did not scale," which is why, shortly after the two co-founders returned from India, the FLORA team began to intensify its work on a second business model.

1.5.2. Brokering pesticide sales

The second and, for now, final step in FLORA's efforts to extract revenue from PHYTØ consisted of developing a business model to transform the app into an e-commerce platform for pesticides and other inputs. More precisely, the new business model envisioned FLORA as a digitally-enabled wholesaler brokering sales between farmers and pesticide retailers, on the one hand, and pesticide retailers and input producers, on the other. To commercialize this brokering, the startup planned to charge commissions on the additional sales that its app would generate for input producers. In turn, the platform was meant to be free of cost for farmers and pesticide retailers. Overall, the development and implementation of this new business model consisted of three major operations, the exact realization of which emerged as the startup progressed: The first operation was to attract pesticide retailers as a new user group. The second operation was to attract input producers as business partners. The third operation was to scale up the business model.

To begin with the first operation: FLORA's pivot from the first to the second business model was not necessarily a smooth process. As Kosmo recounts in the next quote, the initial commitment to a new business model within the FLORA team was quick but smooth:

> "And then we said relatively late, probably last year [2018] October, November, after we were back [from India]: 'Okay it doesn't work like that. We might do this data thing but not now, and we're not going to go out and pitch with it now, because that just brings too many problems. Let's rather do something that directly benefits the farmer.' And that's when this idea came up: 'Yes, why don't we just make sure that we link the farmer with the local retailer? That we operate as a digital doctor who issues you a prescription, and with this prescription you go to the retailer and pick up exactly what you need.'"

In short, due to the sobering experience Wanda and Kosmo had with potential Plant Pro customers in India, the startup decided to switch to an entirely new business model shortly before the search for new funding began. As Kosmo put it, this business model envisaged that PHYTØ acted as a "digital doctor" issuing "prescriptions." In other words, PHYTØ was supposed to act as a digital link between farmers and pesticide dealers. However, Kosmo went on to explain, this time it was more difficult for them to attract venture capitalists to invest in their idea:

> "So, we went out and tried to raise money with that idea. And the problem we had, maybe because we were a little naïve, was that everyone said: 'Do you have any proof for this? Have you ever tried this somewhere?' And we didn't. We had already conducted interviews with the farmers, we had conducted interviews with the stores, but we were not yet technologically ready to deploy it, and that's why the whole thing was a bit more difficult, because everyone said: 'Yes, I think it's super interesting. But I would really like to see proof that the whole thing works.' And that's why it has dragged on a bit longer."

Hence, as with the problem of "traction," the FLORA team had to demonstrate that the second business model they had come up with could actually be realized in the way they had envisioned. In other words, they needed to demonstrate that PHYTØ could indeed act as a mediator between farmers and pesticide retailers.

To this end, as of June 2019, FLORA regularly dispatched small teams of employees from its regional offices in India[24] to surrounding towns and villages to "onboard" pesticide retailers. In addition to explaining how PHYTØ worked, this onboarding consisted mainly of collecting the inventory of the pesticide retailers they spoke to. The reason for this was that, after a successful diagnosis, PHYTØ was supposed to show its users only the products pesticide retailers in their vicinity actually had in stock. In bi-weekly PowerPoint presentations given online to the entire FLORA staff, the teams from FLORA's Indian regional offices documented their incremental progress. For example, in a presentation in June 2019, the office in Northern India reported that five pesticide retailers had been enrolled in the system since the last presentation and ten more would follow in the ongoing week—numbers which would increase rapidly in the months to come.

In addition to the number of onboarded pesticide dealers, at that time FLORA also tracked the number of inbound calls from farmers triggered by a PHYTØ diagnosis, as well as the number of outbound calls made by one of the startup's recently hired call center agents. The reason for hiring these call center agents was that FLORA had not yet automated the mediation between

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[24] In the meantime, FLORA had opened a second regional office in Western India and third regional office Northern India.

pesticide retailers and farmers that PHYTØ was supposed to initiate at that point. In other words, the call center agents were a human aid to simulate (for investors) that PHYTØ would actually be able to mediate between farmers and pesticide retailers once the necessary software was programmed. The envisioned workflow, without call center agents, was as follows: First, PHYTØ was to diagnose a given plant damage on a given image uploaded by a given user. Second, PHYTØ was intended to advise the user in finding the "best solution" to the diagnosed problem. Third, PHYTØ was meant to search for possible "partner shops" in the vicinity of the user. Subsequently, in a fourth step, the user should receive a text message with a summary of the recommendation. Lastly, the user was expected to pick up and pay the respective product at the corresponding shop. However, until PHYTØ was able to perform all these steps automatically, all the steps in this workflow that the app could not yet do automatically were performed by human call center agents. Most importantly this included searching the inventory of a given pesticide retailer for the product recommended by PHYTØ and facilitating a transaction between the farmer and the retailer based on this recommendation. The number of calls the startup received or made was therefore to be understood as a preliminary performance measure that provided FLORA, and particularly its investors, with information about the potential pesticide deals between farmers and pesticide dealers that might be brokered by PHYTØ in the near future.

Hence, although the process described above was not yet fully automated, the in-person visits to pesticide retailers and the work of the call center agents provided investors with an early taste of how the app could gain a foothold in India's pesticide markets. In other words, through these efforts FLORA eventually managed to raise an additional round of venture capital. As documented on the website Crunchbase in November 2019 the startup announced that it had closed a Series A round of 6.6 million euros with a London-based venture capital firm as its lead investor and three other venture capital firms as additional investors, including the two firms that had invested in FLORA in previous rounds.

As mentioned above, the second key operation in the development and implementation of FLORA's second business model was to position the startup as a mediator between pesticide retailers and input producers. To carry out this operation, after the successful financing round the team undertook a step that seemed rather unusual for a startup of FLORA's size. More precisely, FLORA used the money from the latest funding round to acquire the startup "INPUT-ZONE" in early 2020. The reason for this move was that INPUT-ZONE had spent the previous years building an e-commerce platform to broker pesticide sales between pesticide retailers and input producers in India. Hence, by acquiring the startup FLORA absorbed its workforce, its expertise regarding India's pesticide market, and its digital infrastructure.

On the technical side, the most important element of this acquisition was that FLORA replaced a provisional app which it had developed to connect its new user group, pesticide retailers, with farmers and input manufacturers with the much more sophisticated e-commerce app that the INPUT-ZONE team had developed in the years prior. FLORA called this recycled app "PHYTØ MERCHANT" or "MERCHANT" for short. Simply put, while PHYTØ was primarily tasked with linking farmers and pesticide dealers, MERCHANT was to link pesticide dealers and producers of pesticides and other inputs. FLORA intended to play a wholesaler role in the latter of these processes by approaching producers, purchasing in bulk, and supplying farmers with "quality products."

While INPUT-ZONE had already established some contacts in the input industry, after the acquisition the FLORA team continued to work on attracting more agrochemical companies and other input manufacturers as business partners to expand the range of products it could offer to MERCHANT users. For the most part, the negotiations with these companies were about setting the terms and clarifying the formalities for selling their products via MERCHANT. Since FLORA offered a new, innovative sales channel these negotiations were often crowned with success. As an example, in a presentation from June 2020, a member of the startup's newly convened "brand inventory" team reported that, up to that point, FLORA had entered into business partnerships with five major pesticide and input manufacturers (both international and Indian), while negotiations were underway with six other major manufacturers. Once again, these numbers should increase considerably in the months ahead.

Once the FLORA team saw that its plan of acting as a mediator between farmers, pesticide dealers, and input producers was working, the startup became increasingly concerned with scaling up its brokering efforts—a move that can be understood as the third core operation in the development and implementation of FLORA's second business model. As an example, in an interview with a startup-centered news website, which was conducted after the acquisition of INPUT-ZONE, FLORA's newly appointed COO announced that his startup was now seeking to "aggressively expand" in India and Southeast Asia and gain "over 10 million farmers" as well as "over 200,000 retailers" as additional users of PHYTØ and MERCHANT within the next three years. This statement is an illustrative example of what Pfotenhauer et al. (2021) describe as the "scalability zeitgeist," that is, a fixation of contemporary innovation discourses on "scaling up." As the authors note, this fixation is probably most visible at present in the rise of platform technologies like Facebook, Twitter, Airbnb, and Uber in the case of which "'vast scale' has become quasi-synonymous with the success of companies that did not exist two decades ago, but now easily reach hundreds of millions of users" (p. 2). In this sense, the quote from FLORA's COO can be interpreted as a signal to investors that PHYTØ intends to follow in the footsteps of the aforementioned platform technologies, thus recalling Bronson and Sengers (2022) point that the influence of Big Tech is increasingly spilling over into the agricultural sector.

As mentioned at the beginning of this subsection, the development and expansion of MERCHANT is still ongoing at the time of writing (mid 2022). However, there is much to suggest that FLORA has so far succeeded in scaling up the new app and its underlying business model. One indicator of this is the progression of the number of pesticide retailers using MERCHANT. While the Indian regional offices of FLORA reported about 40 onboarded retailers in May 2019, in December 2021 the startup's "press and media" website reported that MERCHANT was "trusted by 50,000+ retailers." Another indicator of the tentative scaling of this second business model is the development of the number of brands and products that are being sold via MERCHANT. While in June 2020 FLORA's management team reported, as already mentioned, that five input manufacturers had allowed the startup to sell their products, in December 2021 FLORA's website reported that "40+ brands and 1000+ products" were available via MERCHANT. Yet another indicator for the provisional success of the app is the revenue FLORA was eventually able to extract from it. Without providing exact numbers, the startup reported in a blog post from April 2021 that PHYTØ and MERCHANT's revenue quadrupled during 2020, and that revenue growth is projected to increase as much as tenfold in the first quarter of 2021. So, it seems fair to say that the FLORA collective has managed to turn the combination of PHYTØ and MERCHANT into an asset—for the time being.

Conclusion

This chapter examined how the team of the startup FLORA gradually turned the agtech innovation PHYTØ into asset, where asset is defined as "something that can be owned or controlled, traded, and capitalized as a revenue stream" (Birch & Muniesa, 2020, p. 2). To this end, the chapter reconstructed the assetization process of PHYTØ over a seven-year period (2014-2021). In this period, four phases were distinguished, each characterized by a delineable composition of the FLORA collective and a delineable status of the PHYTØ technology. As this chapter has shown, these phases of PHYTØ's assetization were not planned from the outset. Rather, they emerged over time as a result of continuous changes in both the startup and its technology, which is why this chapter developed the overarching argument to view PHYTØ's assetization as a process of "exploration" (Doganova, 2013). Despite this non-deterministic approach to PHYTØ's assetization, this chapter has emphasized the central role of venture capitalists in guiding the process. Based on this insight, the chapter specified its argument and proposed to consider the trajectory of PHYTØ as a process of exploratory assetization, that is, a process in which an emerging technology serves as a device through which venture capitalists explore a given sector (as in this case the agricultural sector) in the search for untapped human and non-human actors from which new revenue streams might be extracted.

The four phases of this exploratory assetization can be summarized as follows: In a first phase, the soon-to-be founders of FLORA put all their efforts into assembling a first functional version of the technology they had in mind, that is, a precursor of the PHYTØ app and a set of image processing algorithms to be deployed in it. The collective that supported the team's crowdsourcing project at the time consisted primarily of their academic network, amateur gardeners in Germany, and several agricultural experiment stations. In a second phase, the early version of PHYTØ that has emerged from the first phase enabled the FLORA team to enter into negotiations with potential business partners and investors. The result of these negotiations was that FLORA entered into business partnerships with several agrochemical groups, renting out its image processing algorithms, and raised its first round of venture capital funding. In the third phase, FLORA's venture capitalists advised the team of the startup to greatly increase the number of PHYTØ users. FLORA responded to this request by targeting PHYTØ at India where they identified a large number of potential users. In India, a strategic partnership with ICRISAT and its agricultural extension network in particular helped them tap into these users. In the fourth and, for now, final phase in the process of turning PHYTØ into an asset, the FLORA team developed a business model to capitalize on this user base. More specifically, FLORA tested two business models, one based on selling aggregated user data and another one based on brokering sales of pesticides and other inputs, before eventually settling on the latter. At the time of writing (mid 2022), said business model allows the FLORA team to extract a steady revenue stream from PHYTØ (and MERCHANT). In other words, it turns the app into an asset.

What can be learned from the assetization of PHYTØ with respect to the agtech sector and its ties to both Big Ag companies and financial-sector actors? First, the story of FLORA reflects

Bronson and Sengers' (2022) argument that agtech startups strengthen the oligopolistic market position of Big Ag corporations. However, some differences in how this strengthening occurs can be identified between the case of The Climate Corporation, discussed by the Bronson and Sengers, and the case of FLORA, discussed in this chapter. For one, unlike The Climate Corporation, FLORA has so far not been acquired by a major input producer. Instead, the strengthening occurred in two other somewhat more subtle ways: First, FLORA rented out its image processing algorithms in a white-labelled manner to Big Ag companies, which deployed them in company-branded apps to offer new diagnostic services to their customers. Second, a little later, FLORA helped Big Ag companies gain new customers in rural India by acting as a mediator between the respective companies, pesticide retailers, and small-scale farmers. As this chapter has documented, these partnerships with Big Ag were not necessarily the first choice of the PHYTØ developers when they envisioned the future of their app. Rather, the FLORA team perceived them as necessary means to keep the app's development alive. In other words, the FLORA team only gradually got used to its ever-stronger role as a service provider and wholesaler for Big Ag. In short, then, this chapter needs to be understood as an account of how one agtech startup that, like many others, prides itself with the radical transformation of agrifood systems gradually bowed to the politico-economic logics that have dominated these very systems for decades.

Second, the chapter adds to the relatively broad body of literature concerned with the financialization of food and agriculture (e.g., Clapp & Isakson, 2018; Fairbairn, 2020). More specifically, this contribution consists of a detailed account of how the collective of an agtech startup turned an agtech device into an asset (Birch & Muniesa, 2020) from which continuous revenue streams could be extracted, and thus into an object that venture capitalists deemed a worthwhile investment. To this end, the chapter entered into dialogue with existing research on agtech and foodtech startups (Fairbairn et al., 2022; Fairbairn & Guthman, 2020; Reisman, 2021). More specifically, the chapter has complicated a common argument made by those scholars according to which the contemporary proliferation of agtech devices should be seen primarily as a manifestation of "technological solutionism" (Morozov, 2013). To recall, by "technological solutionism" Morozov means the transformation of complex societal problems into smaller problems as a function of the technologies available to a given tech company, which sometimes results in the tech companies working on "problems" that Morozov describes as "no problems at all." As already mentioned, the findings of this chapter concur with the position of the above-mentioned agtech and foodtech scholars to the extent that they reflect how FLORA translated the complex problem of food security into a simpler technical solution. Still, the chapter would not go so far as to accuse the startup of technological solutionism and claim that the problems it is working on are not problems at all. To get around this prevalent criticism levelled at agtech startups, the chapter has introduced the concept of "exploration" (Doganova, 2013), a concept that allows to take the problems of agtech startups seriously. It has shown that the technologies agtech startups work on (and the ones they work with) cannot be regarded as fixed variables in the problem-solving process of agtech startups, but that they constantly change in relation to the social worlds they interact with. Simply put, it can be said that the chapter advocated for a more generative view of agtech startups than the concept of "technological solutionism" allows. The generative element in the case of PHYTØ was that the app was gradually turned into a device through which venture capitalists indirectly searched agrifood systems for untapped human and non-human actors from which to extract new revenue streams—a process that has been labeled "exploratory assetization."

2. Making plant pathology algorithmically recognizable

Summary of the chapter in French (for formal reasons): 2. Rendre la phytopathologie reconnaissable par des algorithmes

Le deuxième chapitre aborde la question de savoir comment FLORA construit les algorithmes de reconnaissance d'images déployés dans PHYTØ. Il examine comment dans ce processus—qui est essentiellement un processus de classification (Bowker & Star, 1999)—certains aspects de la pathologie végétale sont sélectionnés pour être reconnus par PHYTØ tandis que d'autres aspects de la pathologie végétale sont négligés. En suivant Bechmann et Bowker (2019), le chapitre soutient que la construction d'algorithmes de reconnaissance d'images peut être conceptualisée comme une séquence de « couches de production de connaissances ». Par la suite, le chapitre identifie cinq de ces couches qui constituent la construction des algorithmes de reconnaissance d'images de PHYTØ, à savoir « définir les problèmes », « générer des données », « préparer les données », « façonner les algorithmes » et « représenter les résultats ». En outre, le chapitre démontre qu'à chacune de ces couches, le phénomène de la phytopathologie est soumis à diverses pratiques de « sélection » (Lynch 1990) pour le rendre reconnaissable par les algorithmes. Le résultat de ces pratiques est que les algorithmes déployés dans PHYTØ reconnaissent certains aspects du phénomène de la pathologie végétale tout en ignorant d'autres aspects - une condition que le chapitre appelle la reconnaissance sélective de la pathologie végétale par PHYTØ. Dans la tentative de discerner un schéma dans cette reconnaissance sélective, le chapitre montre que PHYTØ est bien adapté pour reconnaître des dommages isolés sur des cultures isolées, tout en négligeant largement ce que le chapitre appelle les « entre-deux » de la pathologie végétale (par exemple, les différences entre les variétés de cultures, les dommages multiples sur une même feuille, la gravité des dommages sur les feuilles, la propagation des dommages sur le terrain). Sur cette base, le chapitre conclut que la reconnaissance sélective de la phytopathologie par PHYTØ, dans son état actuel, semble être particulièrement propice à des modes d'exploitation agricole plus intensifs en pesticides, car les connaissances non produites concernant les entre-deux susmentionnés est particulièrement important pour les approches de la protection des cultures qui préconisent une réduction de l'utilisation des pesticides, comme le « integrated pest management » (IPM), l'agroécologie ou l'agriculture biologique. En outre, il est important de souligner que le chapitre adopte la position que cet effet, qui pourrait être considéré comme un biais en faveur de l'utilisation des pesticides, est involontairement inscrit dans PHYTØ et ne résulte pas d'une intention malhonnête.

Introduction

In the past few years, image recognition algorithms have been applied to a growing number of classification tasks in agrifood systems. Not long ago, the agricultural machinery company John Deere, released a field sprayer that deploys image recognition algorithms to identify and kill weeds, in real time, while moving across a piece of land. Other companies like RSIP Vision commercialize algorithms for sorting and grading fresh agricultural products that can be integrated into industrial production machines. Still other companies, like BASF, Bayer, or FLORA, the startup around which this thesis revolves, develop mobile apps that feature algorithms for diagnosing plant damages based on digital images of their symptoms. Given this proliferation of image recognition algorithms in agriculture, this chapter looks at the case of FLORA to examine the work through which such algorithms are made, and the particular ways in which these devices come to recognize agricultural phenomena.

This chapter builds on two primary bodies of scholarship. First, it builds on a growing body of STS-informed scholarship concerned with the problematic effects of both agricultural big data (Bronson 2019; Bronson and Knezevic 2016; Carbonell 2016) and algorithms (Carolan 2020; Miles 2019) on rural societies and environments. A common critique raised in this body of literature is that contrary to the lofty promises generally associated with agricultural big data and algorithms (e.g., alleviation of food insecurity, reduction of pesticide use, democratization of knowledge), they often lead to a repetition or exacerbation of agriculture-related problems of past decades (e.g., concentration of corporate power, land grabbing, propagation of monocultures)—a dynamic that Bronson refers to as "design bias" (Bronson, 2022). To shed light on how this dynamic comes about, the chapter mobilizes a second body of scholarship specialized in the ethnographic examination of algorithms in the making (Bechmann and Bowker 2019; Jaton 2017, 2021). Adhering to the methodological approaches developed by these scholars, this chapter explores how FLORA's algorithms are constructed in situated practices and how these practices unintentionally inscribe certain patterns of recognizing and not recognizing the phenomenon of plant pathology into these devices that might be labeled as a bias. In other words, instead of describing algorithmic biases in agriculture in hindsight, this chapter aims to reconstruct how they emerge, in order to identify potential avenues for adjustments.

More specifically, following Bechmann and Bowker (2019), the chapter shows that the construction of image recognition algorithms can be grasped as a succession of "layers of knowledge production" such as the layer of data generation, or the layer of data preparation, to name two examples. The chapter demonstrates that at each of these layers the phenomenon of plant pathology is subjected to different practices of "selection" (Lynch 1990) to make it algorithmically recognizable. These practices allow the team of the startup to develop a set of algorithms capable of recognizing some aspects of the phenomenon of plant pathology, while at the same time excluding other aspects of the phenomenon from recognition—a double movement that the chapter labels as the selective recognition of plant pathology. In a little more detail, this selective way of recognizing plant pathology can be summarized as follows: the startup's algorithms recognize the phenomenon of plant pathology as a finite list of isolated plant damages on isolated crops (at the time of writing 500 plant damages on 30 crops). In turn, aspects that could be labeled as the "in-betweens" of plant pathology are gradually excluded from recognition through the app (e.g., multiple plant damages in one leaf, severity of plant damages on leaves, spread of plant damages in fields, rare plant damages, rare crops, crop varieties in general, etc.). Based on this insight the chapter concludes that PHYTØ's selective recognition of plant pathology, in its current manifestation, seems especially conducive to more pesticide-oriented ways of farming. This is not because farmers who do not want to use pesticides cannot benefit from PHYTØ's diagnoses, but because knowledge of the unrecognized in-betweens of plant pathology is more vital to less pesticide-oriented farming practices or approaches to crop protection such as IPM, agroecology, or organic farming than it is for farmers who simply want to find out which pesticide to spray.

To advance this argument, the remainder of this chapter is organized as follows. Section one reviews existing critiques of agricultural big data and agricultural algorithms, before making a case for studying agricultural algorithms in the making. In addition, it discusses in more detail what is meant by the theoretical argument that FLORA's employees, in constructing new algorithms, engage in practices of selection. The following five sections support this argument empirically by examining the successive layers of knowledge production that give rise to PHYTØ's image processing algorithms. Section two describes the layer of "defining problems," that is, how the employees of FLORA (mainly plant specialists and computer scientists) decide which plant pathological problems PHYTØ is supposed to address. Section three looks at the layer of "generating data," while focusing on a group of trained specialists, the so-called "picture hunters" that FLORA entrusts with this work. The three remaining sections are based on two interviews with FLORA's lead computer scientist for machine learning matters. Since it was not possible to observe him during his work, the interviews were conducted based on a PowerPoint presentation that he had created to explain the most important components of his work to investors for due diligence purposes. With this in mind, section four explores the layer of "preparing data." Section five looks at another crucial component of the computer scientist's work, namely the layer of "shaping algorithms." Lastly, section six scrutinizes the layer of "representing results," that is the ways in which the computer scientist and other software developers at FLORA define how PHYTØ displays its final diagnoses to users. This is followed by a conclusion that summarizes the chapter's main findings, and their contribution to broader debates on agricultural big data and agricultural algorithms.

2.1. Studying the selective recognition of agricultural algorithms

This first section provides a theoretical and methodological introduction to the empirical analysis of the chapter. Subsection one reviews critical research in social sciences and humanities on agricultural big data, as these debates provide common reference points for debates on agricultural algorithms. Subsection two discusses debates on agricultural algorithms and explains how the chapter aims to contribute to them. Subsection three suggests a theoretical framework for this task, delineates the corresponding research questions, and elaborates on the theoretical underpinnings of the argument that the chapter formulates with regard to them.

2.1.1. Promises and pitfalls of agricultural big data

The ascent of image recognition algorithms in agriculture is best understood in light of the rise of agricultural big data. As Kitchin (2014) puts it, "Big Data is not simply denoted by volume" but rather by "being generated continuously, seeking to be exhaustive and fine-grained in scope" while also being "flexible and scalable in its production" (p. 2). Given the compatibility of these characteristics with the data-intensive nature of modern farming, it was not long before the enthusiasm for big data spilled over into the agricultural sector. Consistent with general discourses on digital agriculture, the introduction of big data-driven technologies on farms is often accompanied by the promise that their enhanced analytical capacities will help to feed the world's growing population amid increasingly harsh environmental conditions (e.g., Voegele, 2018). By contrast, STS-oriented scholars have considered the rise of agricultural big data from slightly different perspectives concurring in a rather critical assessment of its effects on agrifood systems.

As already mentioned in the introduction of this thesis, an early commentary concerning the issue comes from Bronson and Knezevic (2016) who reflect on how novel big data collection and analytics tools affect power relations among actors in agrifood systems (e.g., farmers, agrochemical companies, governments). To quickly recall their line of reasoning, the authors situate their research at the intersection of critical data studies and critical food studies, and stress that “Big Data is poised to reproduce long-standing relationships between food system players” (p. 3). As an example of this big data-induced reproduction of long-standing power relations they invoke Monsanto’s Weed ID app. As the authors explain the app strengthens the company’s dominant market position by helping users identify weeds and map weed pressures for free while at the same time “promoting proprietary chemicals and identifying new chemical needs and therefore areas of possible investment in research and development” (p. 2). Elsewhere, Bronson also highlights how the decisions of the developers of agricultural big data technologies “privilege large-scale and commodity crop farmers” (Bronson 2019, p. 5). In other words, she points to another long-standing power relation within agrifood systems that is likely to be reproduced through big data-driven agricultural technologies.

Focusing on the case of Monsanto’s acquisition of The Climate Corporation in 2013, Carbonell (2016) examines “the ethics of big data in agriculture” (p. 1)—another study, which was briefly touched upon in the introduction to this thesis. Similar to Bronson and Knezevic, Carbonell argues that this high-profile acquistition is indicative of a broader big data-induced power shift from farmers to corporations. More specifically, she describes this power shift as being rooted in two closely related dynamics: First, a dynamic that she refers to as the “big data divide” by which she means that “[b]ig data, as a tool for revealing hidden patterns, requires large mobilisations of technologies, infrastructure, and expertise, which are much too elaborate for an individual farmer” (p. 2). In short, she argues that big data excludes certain groups of farmers from becoming users. Second, Carbonell underscores that “[b]ig data and analytics on conventional industrial farms […] focus almost exclusively on inputs and production” while neglecting, for example, “industrial agriculture externalities and vulnerabilities”—an effect that she summarizes as the “selective use of big data in industrial agriculture” (p. 3). In brief, Carbonell highlights that big data-driven technologies exclude certain forms of knowledge from being generated or circulated. She is nevertheless optimistic that “power asymmetry may be rebalanced through open-sourced data, and publicly-funded data analytic tools” (p. 1).

While the studies cited so far have placed their main focus on the development and use of big data technologies in Global North countries, similar, if not more dramatic, developments can be observed with respect to the circulation of big data technologies in the Global South. For example, Fraser (2019) has undertaken a comprehensive study of how big data affects farmers in Global South countries. The core argument that he develops is that the increasing proliferation of big data-driven technologies should not be conceptualized as an equitable "exchange" (e.g., user data in exchange for big data-informed services)—as the providers of these devices often do—but as an opportunistic "data grab." Fraser emphasizes that, different from an exchange, data gabbing is characterized by dispossessing farmers of control over their data (e.g., through end-user license agreements). Based on this, he argues that the specificity of the effects of big data-driven technologies in the Global South lies in the close intertwinement of processes of "data grabbing" and processes of "land grabbing." As he puts it, "land grabs in the twenty-first century will pivot on digital knowledge" (p. 13)—an assessment that is consistent with latest research on the financialization of farmland (Fairbairn, 2020).

Fairbairn and Kish (2022) highlight another somewhat related aspect with regard to the role of big data-driven technologies in Global South countries, particularly with respect to small-scale farmers. As the authors argue, big data-driven technologies are often framed as a means to solve "a data deficit among farmers" (p. 3): they are diffused with the rationale that "[f]armers do not have enough information and the information they have is not good enough" (ibid.). As Fairbairn and Kish point out, this common approach of diffusing big data-technologies against the background of supposed knowledge or data deficiencies is problematic because it is largely oblivous of "how the structural residues of colonialism, agricultural intensification, and neoliberal development policies have played a role in producing farmer vulnerability in the first place" (p. 9). Given this observation, they argue that current efforts to diffuse big data-driven technologies in Global South countries enact "a knowledge politics that echoes the past" (p. 9) in that the deficit-centric view of farmers inherent in them bears a strong resemblance to past modernization or colonization efforts.

Taken together, these studies illustrate that agricultural big data is anything but an unproblematic solution to the historically grown problems of agricultural systems around the world. They call to mind that the ways in which agricultural big data is collected, analyzed, and commercialized matter a great deal, since they shape the effects that the technologies in which agricultural big data is used have on the world—an insight that can be applied one-to-one to the object of agricultural algorithms.

2.1.2. Problematic effects of agricultural algorithms

Many, if not all, of the technologies mentioned in the previous section are equipped with algorithms designed to process the ever-growing amounts of agricultural big data with which they are fed. Yet, compared to the attention that the agency of algorithms has received with respect to other application areas like surveillance (e.g., Introna & Wood, 2002), finance (e.g., Muniesa, 2011), or health care (Henwood & Marent, 2019), the explicit attention that these computational devices have attracted with respect to agriculture is rather small. To be precise, in most studies—as in those discussed in the previous section—algorithms are treated as accompanying objects of other phenomena (e.g., digital agriculture, big data, neoliberal agricultural regimes). In other words, they are treated rather in passing. Nevertheless, there is a small number of studies that take agricultural algorithms as their main object of study.

The first important study to mention is an article by Miles (2019) which examines how algorithms shape the rise of digital agriculture. Through an approach rooted in media studies, Miles develops the argument that algorithms have enabled the rise of digital agriculture in two important ways. First, by bringing into being an "algorithmic rationality," that is, a "reorganization of industry and reasoning upon rule-based grounds, fueled by the emergence of capitalism and the liberal nation-state" (p. 5). Second, by giving rise to "algorithmic epistemology," that is, "a fetishization of information that ascribes super-natural divination to digital technology" (p. 5). Building on these considerations, Miles concludes that as long as algorithms are deployed in capitalist systems of production, the knowledge they generate will inevitably lead to a perpetuation of these systems: "In a system economically organized by capitalist rationality, the truths that digital sensors and algorithmic processing speak are the expression of a normative function: the rational logic of capitalist production" (p. 9). In short, Miles argues that agricultural algorithms are first and foremost biased by capitalism.

A second insightful, slightly more nuanced, study of agricultural algorithms comes from Carolan (2020). Invoking Latour's (1999) concept of "chains of translation," he scrutinizes "data value chains" (p. 1) in the development of agricultural algorithms. To do so, Carolan draws on qualitative interviews with "farmers, crop scientists, statisticians, programmers, and senior leadership in firms located in the U.S. and Canada" (p. 1) who, taken together, were involved with 91 different digital agriculture technologies. Additionally, he supports these interviews with observational data. In analyzing this data, Carolan adapts Latour's concern with "chains of translation" in two important ways. First, he blends Latour's focus on epistemic chains of reference with a focus on politico-economic value chains. Second, Carolan does not scrutinize one "chain of reference" from beginning to end but many different ones, in fragments. He argues that the algorithms he studied give rise to "types of lock-in" (p. 2) — "a term used to describe when seemingly small alterations [e.g., to the code] produce immensely consequential pathways that become calcified and resistant to change" (ibid.). To illustrate such lock-ins, Carolan describes, for example, how the algorithms of one technology are designed to analyze only one variety of corn (of the many different varieties grown around the world). In other examples algorithms incentivize the cultivation of field corn and soy over less monoculture-oriented crops or make users unlearn "local analogue knowledge" (p.8) regarding soils or other elements of agroecosystems.

These two studies provide initial insights regarding some of the problematic effects that agricultural algorithms may have on agrifood systems and complement the insights on the effects of agricultural big data outlined in the previous subsection showing that the two phenomena occur in conjunction with each other. However, they do not go into great detail about how these effects come about. Therefore, this chapter proposes a slightly different approach to the study of agricultural algorithms.

2.1.3. The construction of algorithms and the selective recognition of plant pathology

The two studies outlined in the previous subsection say relatively little about the practices through which the problematic effects of the agricultural algorithms they deal with come into existence. Put differently, it seems that Bronson's (2019) argument that social science scholars have primarily "assessed the implications of the use or governance of digital agriculture tools, rather than the ways in which power and authority may be built right into their design" (p. 1) applies quite well to existing social science and humanities research on agricultural algorithms. By contrast, this chapter moves the work of constructing agricultural algorithms to center stage.

To do so, the chapter inscribes itself into a small strand of ethnographic research concerned with the analysis of algorithms in the making (Bechmann & Bowker, 2019; Jaton, 2017, 2021b). As Jaton (2017, 2021) puts it, the necessity of such an approach lies in the problem that the concrete practices involved in the construction, or as he calls it the "constitution," of algorithms are invisible in most cases, and that the invisibility of these practices is not perceived as a positive thing by most of society. To illustrate this "negative invisibility" (Star & Strauss, 1999) of the construction of algorithms, Jaton invokes different examples in which the relative opacity of algorithms caused broader societal controversies. One prominent example is the algorithm behind the Facebook "News Feed," and how it was increasingly criticized for leading to a proliferation of fake news during Donald Trump's election campaign in 2016. Other controversial examples that Jaton invokes are the algorithms that are being used by police departments and secret services to create profiles of potential perpetrators based on aggregated social media data, or the various biases (e.g., gender, age, skin color) that have been identified in facial recognition algorithms over the years (e.g., Introna & Wood, 2002). Even though a little less explicit in their political significance the examples of agricultural algorithms described by Miles (2019) and Carolan (2020) could be added to this list.

In light of such examples, Jaton (2021) argues that looking at the effects of algorithms is only half of the coin. As he puts it, “if sociology has looked, with a certain success, at the effects of algorithms, it is now time for it to inquire into the causes of these effects” (p. 11)—a statement that resembles Bronson’s assessment (2019) cited above. As Jaton goes on to explain, in order to provide all parties involved in disputes over algorithms with “common grounds for negotiation” (p. 18) it is important “to conduct sociological inquiries to make visible the work practices required to make algorithms come into existence” (p. 18). More specifically, Jaton proposes to explore these work practices following the STS tradition of “laboratory studies” (e.g., Latour & Woolgar, 1986), that is, by studying the situated practices that feed into the construction of algorithms in the same way that these scholars have studied the situated practices that feed into the construction of facts. Using this methodological approach, Jaton develops a thick ethnographic description of the work that is carried out at a Swiss computer science laboratory identifying three core activities that constitute the construction of algorithms, namely “ground-truthing, programming, and formulating” (p. 17).

In doing so, an important inspiration for Jaton is provided by a study by Bechmann and Bowker (2019), which also focuses on the construction of algorithms, but takes a more autoethnographic approach. Expanding on Bowker and Star’s (1999) previous work on classification, the article explores “classifications as they arise in artificial intelligence (AI) and machine learning with the aim of making visible knowledge production” (Bechmann & Bowker, 2019, pp. 1-2). More specifically, the authors chose the rather unconventional approach of engaging in the construction of different algorithms themselves, while documenting the classifications they had to undertake in order to make these devices work. Among others, they designed an image recognition algorithm to perform a gender classification based on user images retrieved from Facebook—a task that, on a technical level, is very similar to what PHYTØ does with pictures of plant damages. In developing this algorithm, they identified five important “layers of knowledge production” (p. 1), that is, layers at which they had to perform different types of classification work, namely problem definition, data collection, data cleaning, model selection, and model training. The overriding argument that they advance with regard to this development process is that the classifications that are required to make the respective algorithm work produce potential “discriminatory consequences” (p. 7) which accumulate and translate into the classifications of the final algorithm. They give several examples of such consequences. First, with regard to the layer of problem definition, Bechmann and Bowker mention how their decision to build an algorithm to perform a binary gender classification (for reasons of technical simplicity) discriminated against people who do not define as men or women. Second, referring to the layer of data collection, the authors underline how their choice to design an algorithm for the classification of images of Facebook users excluded images of non-users from consideration, which might result, for instance, in the algorithm classifying people of a certain age group more accurately than others. Overall, they stress that the different classifications that are inscribed into image recognition algorithms may create "problems of visibility, redlining, and other discrimination such as targeting, favoring, and normalizing some people over others" (p. 2).

Simply put, this chapter translates Bechmann and Bowker's (2019) concern with the construction of algorithms and the accompanying discriminatory effects to the realm of agriculture. Considering that PHYTØ's image recognition algorithms are designed to classify plant damages, the chapter does not scrutinize how their construction process is accompanied by discrimination but by selection. To this end, the chapter draws on a pragmatist conceptualization of selection as developed by Michael Lynch in his research on visualization in scientific work (Lynch, 1990). In said study, Lynch compares different types of visualizations retrieved from textbooks and articles from the life sciences explaining that "[s]election concerns the way scientific methods of visualization simplify and schematize objects of study" (p. 153). To clarify this concept of selection, Lynch shows two so-called "split-screens." These split-screens are visualizations of which one half consist of a photograph of a biological object (ribosomes, a mitochondrion) and the other half of a schematic drawing of the object. As Lynch argues, the remarkable thing about the respective drawings is that they reduce visual features (e.g., "noise") while simultaneously adding others (e.g., a clear outline of the object). In other words, Lynch underscores that selection in scientific work should always be seen as a simultaneous process of reducing and adding to the phenomena under study, that is, as a process through which a given specimen "loses in specificity and materiality" while gaining "in legibility and (relative) universality" (Lynch, 2006, p. 35) —a theoretical argument that is congruent with Star's concept of "simplification" (1983) as well as Latour and Woolgar's concept of "purification" (1986).

To draw these two theoretical influences together, this chapter proposes that the construction of the image recognition algorithms deployed in PHYTØ must be regarded as a succession of layers, at each of which the team of the startup engages in different selection practices. These selection practices single out certain aspects of the phenomenon of plant pathology and make them algorithmically recognizable, while, at the same time, excluding other meaningful aspects of the phenomenon from recognition. The result of this selection process are visualizations of plant pathology in the form of diagnostic results presented on the smartphone displays of PHYTØ users. Ultimately, these diagnostic results do not only passively depict the phenomenon of plant pathology but redefine or "re-present" (Coopmans et al., 2014) it in a FLORA-specific way that will be analyzed in the remainder of this chapter.

For this purpose, the chapter addresses the following two closely related questions. How do the employees of FLORA (mainly plant specialists and computer scientists) construct algorithms for the recognition of plant pathology? How do they select the aspects of plant pathology that are to be recognized by the algorithms and those that are not?

2.2. Defining problems

The first layer in the construction of PHYTØ's algorithms consists of defining the problems that the app is supposed to solve. The analysis of this layer builds on scientific articles concerning the development of image recognition algorithms for plant pathology, interviews with two of the co-founders of FLORA, and interviews with two of the plant pathology experts working for the startup. As will be shown, the two main selection practices at this layer deal with deciding on a machine learning problem and prioritizing crops and plant damages.

2.2.1. Deciding on a machine learning problem

A foundational selection practice at the root of all algorithms developed by FLORA is the initial decision on the type of machine learning problem that each algorithm will solve. In the case of PHYTØ, this problem is always the same, namely classifying crops and plant damages.

As already mentioned in the first chapter, the co-founders of FLORA got the idea for PHYTØ from reading an agricultural informatics article with the title "Digital image processing techniques for detecting, quantifying and classifying plant diseases" (Barbedo, 2013). As its title suggests, the article undertakes a review of computational methods to address the closely related machine learning problems of detecting, quantifying, and classifying plant diseases based on digital images of their symptoms. Detection refers to a problem in which an algorithm is required to detect one plant damage among many possible plant damages that the algorithm is not required to detect. Quantification refers to a problem in which an algorithm is supposed to determine the severity of a plant damage by evaluating the surface area that its symptoms cover on a given leaf. Classification refers to methods that aim to recognize "whichever pathology […] is affecting the plant" (p. 6).

One of the classification methods described by Barbedo are so-called "neural networks," the type of machine learning method, which the co-founders of FLORA decided to use for the development of PHYTØ. As examples for the use of this method Barbedo cites a study in which Sanyal et al. (2007) propose a neural network to classify six different mineral deficiencies in rice plants. Another example he mentions is an article by Kai et al. (2011) in which the authors train a neural network to recognize three kinds of diseases in maize. In light of such examples, Barbedo emphasizes that he sees great potential in using neural networks for the classification of plant damages, whereas he also criticizes that the algorithms that are suggested in the respective articles are far "too specific" (p. 10). As he puts it:

> "The ideal method would be able to identify any disease in any kind of plant. Evidently, this is unfeasible given the current technological level. However, many of the methods that are being proposed not only are able to deal with only one species of plant, but those plants need to be at a certain growth stage in order to [sic] the algorithm to be effective" (ibid.).

In a way, PHYTØ can be understood as a startup-driven response to this criticism of a too high degree of specificity. As one of the co-founders recalled in an interview, they contacted Barbedo shortly after reading his 2013 article to discuss their idea of developing a mobile app capable of diagnosing greater numbers of plant damages on a greater number of crops. In the following quote, the co-founder paraphrases the response they received from the scientist: "I remember that he wrote: 'That would be the perfect thing to do, but nobody has such a big database.' [Laughs] And then it was triggered somehow."

To wrap up, Barbedo's research illustrates the extent to which the decision for a machine learning problem is a selection practice. In the case of FLORA, the decision was made in favor of algorithms that address the phenomenon of plant pathology as a classification problem. Simultaneously, at least in the case of FLORA, the decision for classification algorithms went hand in hand with a decision against equipping PHYTØ with quantification algorithms, to name but one example. As a result, PHYTØ is not capable of assessing the severity of a given plant damage before recommending a pesticide.

2.2.2. Prioritizing crops and plant damages

The second important practice in defining the problems to be addressed by PHYTØ consists of selecting the crops and plant damages that ought to be recognized by the app's algorithms. As indicated in the previous subsection, developing image recognition algorithms requires resources. Like their counterparts in academia, the developers of PHYTØ must therefore prioritize some crops and plant damages over others when developing new image processing algorithms.

As the head of FLORA's plant team recalled in an interview, in prioritizing the crops that ought to be covered by PHYTØ they initially relied primarily on publicly available FAO statistics to find out "which crops were grown the most, globally." Subsequently, as the startup developed a focus on specific countries (e.g., Brazil, Mali, India), they used the same statistics to get an idea of the crops that were most widely grown in these countries. In addition, they consulted local experts to further refine the "crop lists" they had compiled based on FAO statistics. As explained in chapter one, since 2016, India has become FLORA's predominant target region. This focus is echoed in the selection of crops and plant damages covered by PHYTØ's image recognition, which include a higher proportion of crops and plant damages that occur in tropical and subtropical climates than, for example, in cool temperate climates. With that being said, the more images FLORA received on a daily basis, the more independent the startup became from external statistics. As explained by the head of the plant team, once they had managed to establish a stable flow of incoming images, they created their own prioritizations of crops which were supposed to be more attuned to the requirements of PHYTØ users. In an interview, he summarized these requirements as follows:

> Half a year ago or three quarters of a year ago we made an evaluation: What are the ones [crops] that our users really demand? […] For example, cassava is huge in India, but we get almost no pictures for it, because it simply has fewer diseases. Coffee, tea and whatever else; it is simply not requested. They have extension managers with whom they work. So, just because it's grown a lot in a country, it doesn't always mean it's PHYTØ. And sometimes people don't see it at all. They just look at the export and say: 'Tomatoes are not that high. Potatoes are much higher.' But in this database, tomatoes are actually quite high, because everyone has that in their backyard.

As this quote captures, at a certain point, the FLORA team began prioritizing crops based solely on the absolute number of images of crops uploaded by users—an approach they summarized as "PHYTØ users first." As is equally reflected in the quote, in doing so they adopted a relatively egalitarian concept of users, in which they did not give different weights to images of commercial farmers, subsistence farmers, or amateur gardeners.

In the same vein, the FLORA team needed to prioritize the plant damages that were supposed to be recognized by PHYTØ. A long-time employee of the plant team put it like this: "You have to find your enemies. […] You can't start at A and in two years you'll be at Z. You just have to find the most important pathogens […]." As the employee continued to explain: "There are 100 different pathogens per crop. You can't build a database for everything, but you can work through the twenty most important ones." Hence, in this case, too, the number of plant damages for the recognition of which FLORA develops algorithms is limited by time, money, and other resources, forcing the startup to select, whereas the team has set itself the goal that PHYTØ should recognize at least 10 plant damages per crop considered. To this end, as with crops, the FLORA team initially relied on publicly available statistics, scientific literature, and expert opinions to establish a first hierarchy of plant damages. Subsequently, once the startup had established a sufficient number of incoming images per day, FLORA's plant team began to increasingly examine this stream of incoming images (through human diagnostic work) to identify plant damages that occurred frequently on the pictures uploaded by PHYTØ users.

In summary, then, prioritizing crops and plant damages is an important selection practice, since it pretty straightforwardly defines which crops and plant damages will be recognized by PHYTØ, and which will not. In this endeavor, the FLORA team is predominantly guided by the number of images that are uploaded by PHYTØ users. As should have become clear, this pragmatic "PHYTØ user first" approach is just one of many possible approaches to evaluating the importance of crops and plant damages. In that sense, it inevitably rules out other metrics like the export volume of a given crop, the area on which this crop is cultivated (e.g., considered by the FAO), or the spread of a given plant damage in a given field, to name but a few examples. Besides that, given the magnitude of the task, FLORA's prioritization of crops and plant damages rules out the recognition of individual crop varieties and their relation to plant damages all together. The resulting lists of crops and plant damages recognized by PHYTØ pave the way for the next layer in the construction of the app's algorithms, namely generating the data that is required to do so.

2.3. Generating data

The second layer in the construction of PHYTØ's algorithms consists of generating data regarding the crops and plant damages that the app is supposed to recognize. The empirical material used to describe this layer consists of observations, interviews, and documents centered on FLORA's so-called picture hunters, a group of trained specialists employed by the startup to generate data in a targeted fashion. The two most important selection practices at this layer deal with "hunting" and taking good pictures.

2.3.1. Hunting pictures

Most of the data that FLORA requires to develop new image recognition algorithms is generated through a practice that the team of the startup refers to as picture hunting. In brief, picture hunting means sending workers with plant pathology expertise into random or pre-selected fields to take pictures of specific plant damages occurring on specific crops. In concrete terms, this means that whenever the FLORA team decides that a particular plant damage should be added to PHYTØ's diagnostic portfolio picture hunters are sent out to photograph that plant damage on all crops considered by PHYTØ on which that particular plant damage may occur. FLORA has been relying on picture hunting since its beginnings in Germany in 2014. As mentioned before, in 2016, FLORA began to focus PHYTØ almost exclusively on India as a target region. To accomplish this "localization" of the app, in the peak phase of its picture hunting efforts, between 2018 and 2019, FLORA's regional office in the ICRISAT premises supervised a total of four picture hunters. The startup's regional office in Western India reached the respective peak phase in the period between 2019 and 2020 and supervised the work of six picture hunters in total. Most picture hunters had short-term employment contracts with durations between 3 and 6 months. In October and November 2020, when the interviews that inform this subsection were conducted, only one of these ten picture hunters was left.

In their work, the picture hunters were supervised by one employee from each of FLORA's two local offices, who were themselves specialists in plant pathology. As these employees explained, the supervision of picture hunters mainly consisted of communicating the picture hunting targets set by the German FLORA team with the picture hunters, helping the picture hunters to find suitable fields to take the respective pictures and to gain access to these fields, and verifying that the pictures taken by the picture hunters meet the quality criteria defined by the FLORA team (which will be discussed in greater detail below). In carrying out this work, the two supervisors of the picture hunters had quite different strategies, which are tied to their different professional backgrounds and networks. The supervisor from the office in Western India, who had worked as an agricultural extension agent before joining FLORA, for example, offered free extension services in exchange for farmers informing him about plant damages in their fields and granting the picture hunters he managed the right to take pictures of these plant damages. He explained this strategy as follows:

> "So, the basic question for the picture hunter is where do they get the images? If the farmers don't allow them to enter in their field, they will not get the images. So, I need to train the picture hunters as well as the farmers. Because I meet the farmers. They say: Sir, I am having this issue. Then, I say to the picture hunter: Go to his field. He has an issue with the cotton bollworm. Send the 2000 images as well as give him these kinds of remedies."

The supervisor of the office near Hyderabad, on the other hand, had a background in plant sciences and genetics, and was still affiliated with ICRISAT for research purposes while carrying out her work as a supervisor of picture hunters. She rather used statistical surveys and her institutional contacts to identify suitable fields and provide picture hunters with access to them. As she put it:

> "I will report to [members of the German plant team] that a picture hunter is surrounded by particular crops, nearby his place, for example rice, cotton, banana, something like that, five to six crops, which are majorly cultivated in that area. […] Beyond that list, I will instruct them [picture hunters] to go to research stations. In research stations particular crops will be there. So, they can go. Even I used to go collect some pictures in research stations, if I need any specific crop, banana something like that, rice. If I need any particular crop, I will go, and I will also participate with picture hunters in picture collection sometimes."

One important aspects of these accounts is that they highlight that, contrary to the association of an individual's chase of naturally occurring pictures that the term "picture hunting" may evoke, picture hunting is a highly organized, and collective practice that carefully produces the pictures that FLORA deems relevant for the further advancement of PHYTØ. As such the practice of picture hunting bears a strong resemblance to practices of constructing "raw data" that Denis and Goëta's (2017) have observed in French public administration agencies.

In February 2019, during my fieldwork in India, I was given the chance to meet with one of FLORA's picture hunters, a young man named Amar, who lived in the city of Bapatla. More precisely, one of the employees of FLORA's regional office near Hyderabad, Dinesh, who accompanied me on the six-hour bus drive to Bapatla, had asked Amar if he would be willing to give me an interview, and show me his work, to which the picture hunter agreed. As Amar explained in our conversation, after finishing school he had studied agriculture and then worked as an agricultural extension agent for eight years. In this time, he had been collaborating occasionally with Kumar, the current head of FLORA's office near Hyderabad, and a senior researcher at ICRISAT. Through this professional connection, Amar was eventually offered a job as a picture hunter which he gladly accepted.

After the interview, Amar, Dinesh, and I drove to a nearby village. There I was given the opportunity to observe the actual practice of picture hunting from up close: Having arrived in the village, Amar, Dinesh, and I headed to a nearby chili field. Once we reached the field, we walked along its edge while observing the plants that passed us by. At some point, after a minute or two, the men stopped walking. They both looked at a chili plant that was smaller than the others and whose leaves looked yellowish and shrivelled. The plant looked sick. Standing in front of the plant, the two men exchanged a few sentences in Telugu which I did not understand. At some point, Dinesh bent down to the plant, and broke off a stem holding it in front of them for closer examination (see Figure 2). After a couple of seconds, the men seemed to have reached an agreement. At least, Dinesh dropped the stem to the ground, and Amar took a smartphone out of his pocket, preparing himself to take a picture of the sick plant. To do this, he swiped and tapped the screen of his smartphone a few times (see Figure 3), bent his knees slightly, and then took several photos of the plant from slightly different angles and distances.

Figure 2: Examining diseased chili plant (Source: Photo taken by the author)

Figure 3: Taking a picture of diseased chili plant (Source: Photo taken by the author)

The app that Amar used for this work was not PHYTØ, but a different app called COLLECTØ which the FLORA team had developed specifically for the purpose of picture hunting. As COLLECTØ is a tool for data generation alone, the app does not provide diagnoses. Instead, it asks its users to identify both the crop and the plant damage they intend to photograph themselves. Through this interface design COLLECTØ generates pictures that are referred to as "labeled," that is, equipped with a digital name tag indicating the depicted crop and plant damage—an important prerequisite for FLORA's actual training of new algorithms.

To wrap up, I argue that the practice of picture hunting constitutes a practice of selection in that it reduces the messy phenomenon of plant pathology as it occurs in the field into a narrow set of "inscriptions" (Latour & Woolgar 1986) of plant pathology—namely digital images and name tags of crops and plant damages—that can be used to develop new image recognition algorithms. In this process, picture hunters are not required to generate any plant pathology-related inscriptions that go beyond this narrow selection, such as inscriptions of biodiversity in the field, environmental stresses, or cultural practices. This narrow focus translates into how PHYTØ recognizes plant pathology.

2.3.2. Taking good pictures

Besides searching, identifying, and labeling crops and plant damages, picture hunters are expected to photograph them in a particular way. Thinking back to the previous subsection, Amar did not take the photos of the diseased chili plant just anyhow. Instead, he positioned his body and his smartphone in front of the plant in a way that seemed to follow a certain protocol.

This protocol is captured in a PowerPoint presentation created by two members of the German FLORA team to teach prospective picture hunters how to take "good pictures" for the development of new image recognition algorithms. As the presentation explains on the first slide, "[a] crucial limitation of image recognition performance has to do with picture quality" specifying that if the images that are used for developing new algorithms are of "bad" quality the classification performance of these algorithms will also turn out to be bad. To prevent this, the presentation continues, "[t]he next slides show examples of 'good' and 'bad' pictures."

To explain this distinction, the presentation lists six qualities which, according to its creators, determine whether pictures count as good or bad. These criteria are "distance," "sharpness," "brightness," "background," "camera (settings)," and "reflection." The presentation then devotes one slide to each of these qualities providing sample images and brief instructions. The slide dedicated to "distance," for example, shows three pictures of entire crops instead of their leaves alone and explains "Plants are too distant. Details are lacking. You can't see any symptoms." In a similar vein, the slide concerned with "reflection," presents four images with strong light reflections and provides the explanation that "Backlight, sunlight and flash may cause reflections that disturb a good performance." These examples primarily illustrate how the FLORA team attempts to teach picture hunters how PHYTØ's nascent algorithms process digital photographs. In other words, the presentation is meant to teach picture hunters an algorithm-centric way of looking at plant pathology—a way that is quite different from how human plant pathology experts might look at them.

The difference between these two ways of looking at plant damages is most noticeable on the slide concerning the quality criterion background. To familiarize prospective picture hunters with the peculiarities of the quality criterion background, the slide shows several pictures from FLORA's database that, while all displaying manifestations of plant damages that would likely be recognized by a human specialist—as the depicted crops and symptoms of plant damages can be seen well—likewise contain backgrounds that are likely to diminish the diagnostic performance of PHYTØ's nascent algorithms by containing atypical features. As an example, a photo on the slide shows a leaf with distinct yellowish discoloration—a clear indication of a plant damage. However, while taking the photo, the user who uploaded the picture held the leaf in front of the rear of a silver car, which is clearly visible in the background. The slide criticizes this practice by explaining that in that image the "[m]ost visible patterns stem from background." Another example contained on the slide is a shriveled leaf with light lesions lying on a colorful patterned surface that could be a tablecloth or a piece of wrapping paper. In this case, the slide criticizes that "[a] lot of artificial background is shown."

As can be inferred from these examples, although the leaves of the crops and the symptoms of the plant damages that affect them are clearly visible in the images, the images are considered as "bad" because their background is either too "artificial" or has too "visible patterns." In other words, even though the images may be meaningful to the eye of a human plant pathologist, they count as bad within the startup and will not be used in the development of new image recognition algorithms because they do not meet the technical quality standards prescribed by PHYTØ's nascent algorithms.

Given this, the point of this subsection is that taking good pictures constitutes a selection practices or a selection imperative in that it further narrows the selection of inscriptions of plant pathology that picture hunters are expected to produce. On the one hand, this imperative leads picture hunters to generate a relatively high proportion of images that can be used to develop algorithms that "perform well." On the other hand, it sets a new norm of what counts as plant pathology ("good pictures") and what does not ("bad pictures"), which is shaped more by the technical requirements of PHYTØ's algorithms than by plant pathological reasoning, just as in the figure above, where manifestations of plant damages visible to the human eye are classified as "bad" because they do not meet the technical requirements of the algorithm.

2.4. Preparing data

The third layer in the construction of PHYTØ's algorithms consists of preparing the data that reaches the servers of the startup. The empirical basis for the description of this layer is formed by interviews with, and observations of, two FLORA employees (computer scientist, plant specialist) in charge of this work. The two primary selection practices at this layer are sorting out "garbage" and labeling pictures.

2.4.1. Sorting out garbage

A first important practice in preparing the images uploaded by regular PHYTØ users on a daily basis consists of sorting out the ones that do not depict crops or plant damages, or as the team of the startup puts it, images that depict "garbage." The remaining images of crops and plant damages, that is, the ones that are not sorted out, serve the team of FLORA to supplement the images collected by the picture hunters.

As the employee responsible for maintaining FLORA's image database explained in an interview, the ratio of these discarded images is relatively high: "[W]e are at 40,000, 50,000 pictures a day, but you have to consider, about 50 percent of them are some kind of fooling around, so, garbage, not a plant." To be precise, the FLORA team distinguishes only between two categories, "garbage" and "interesting." In the early days of FLORA, the work of assigning images to these categories was carried out by human freelancers who worked remotely. Relatively shortly after the launch of PHYTØ, however, these freelancers were replaced by an image recognition algorithm, capable of distinguishing whether a given picture depicted a plant or not. As in the case of any image recognition algorithm, the classifications of this algorithm are not always correct. As an example of a typical source of error, the computer scientist mentioned that the algorithm would sometimes classify pictures of certain atypically looking flowers as "garbage," since it is not attuned to their visual patterns.

Hence, sorting out "garbage" is a selection practice in that it filters the images that reach the servers of the startup every day. On the one hand, this practice is meant to maintain the quality of FLORA's image database and, as a consequence, of its algorithms, since it keeps out most images that do not depict crops or plant damages. On the other hand, it can lead to what might be referred to as collateral damage, in that pictures of atypical crops or plant damages are excluded, because the algorithm that does the sorting is not accustomed to their visual patterns.

2.4.2. Labeling pictures

The second, and more time-consuming, practice in preparing FLORA's data consists of "labeling" it. The notion of labeling designates the practice of attaching a digital name tag to a given picture. The computer scientist responsible for training PHYTØ's algorithms explained the need for this work as follows:

> "A picture that is interesting alone could not be used for training because no disease has been annotated. So, the AI would not even know: Well, what is that anyway? This is just an interesting picture which is not garbage. So, you can just see a plant, but there is no crop attached to it. Maybe there is already a crop, from the crop net, but there is no disease attached to it."

In computer science parlance, labeled pictures constitute the "ground truth" of FLORA's nascent algorithms, that is, referential data used to shape and evaluate them (Jaton, 2017). On a practical level, labeling is a two-step practice. Initially, a first specialist is required to attach a name tag of a crop or plant damage to an image she would like to process—a work that is also referred to as “pre-labeling.” This specialist can be both a picture hunter in the field using COLLECTØ or a FLORA employee browsing through the startups database while sitting at a desk in one of its offices. To do so, these specialists use a digital interface called “Kangaroo.” The next step requires a second specialist, also using Kangaroo, to “validate” the label selected by the first specialist. Once this validation is completed, an image counts as “labeled” and is eligible for “training.”

A video tutorial on how to use Kangaroo that is circulated within FLORA, provides an impression of how Kangaroo structures the work of labeling. In the tutorial a FLORA employee searches the startup’s image database for all images of cotton—a search that is executed by FLORA’s already deployed algorithms for recognizing crops. Subsequently, the employee searches the results manually for images of a cotton disease for which the startup aims to develop a new, or refine an existing, algorithm. To facilitate the task of labeling, Kangaroo provides users with additional information related to the displayed images: A light gray box on the left of the depicted cotton leaf lists additional information that was attached to the image in the moment it was taken like “Date,” “Country,” and “User ID.” A light gray box on the right side of the picture shows classification results that the image produced in running through FLORA’s already deployed algorithms. In the example shown in the video tutorial, the algorithms classified the depicted crop as “COTTON” and the depicted disease as “Tobacco Caterpillar” or “Spodoptera litura” with a “55/100” probability. Given all of this information, the remaining task for the Kangaroo user is to decide which disease label to attach to the image on the screen before the image is eventually cleared for validation and training.

So, in summary, labeling is a selection practice in that it determines which images from the FLORA database are used for training new algorithms and which are not. More specifically, labelling prepares parts of FLORA’s data for training new algorithms by equipping it with unambiguous name tags. Simultaneously, labeling creates new residual categories, that is categories of “things that are hard to classify” (Bowker 2000, p. 661) that are being excluded from recognition through PHYTØ’s algorithms (e.g., multiple plant damages in one leaf, atypically looking plant damages, plant damages outside the visual spectrum). This chapter refers to these residual categories as. I suggest to refer to these emerging residual categories that are gradually excluded from being recognized by PHYTØ (on this and on other layers) as the “in-betweens of plant pathology.”

2.5. Shaping algorithms

The fourth layer in the construction of PHYTØ's image recognition consists of shaping the algorithms that are to be deployed in the app. The description of this layer is based on two interviews with the responsible computer scientist, in which a PowerPoint presentation that he had created for due diligence purposes served as a stimulus. The two main selection practices at this layer are preparing datasets and training algorithms.

2.5.1. Preparing datasets

According to the computer scientist, the most work-intensive task in shaping new algorithms is preparing the required datasets. At the time of the interview, FLORA had about 15 million pictures in its database of which about 500,000 were labeled. Again, a smaller proportion of these labeled images, the computer scientist continued, was actually "validated" too, and thus qualified to be included in one of the datasets that he assembled for the training of new algorithms. As he explained it, there is a certain threshold of at least fifty pictures per class[25] below which it would not make sense to begin with the preparation of datasets.

Provided that this threshold is met, the next important task that the computer scientist performs is splitting the images into a "training" set and a "test" set, wherein he puts two-third of the images in the former and one-third in the latter. The training set serves him to extract the visual patterns of the crops or plant damages that are depicted on the images it contains and to translate these patterns into machine-readable code. The result of this work is an algorithm that has "learned" the visual patterns of all the images contained in the training set. In a second step, the resulting algorithm is evaluated by being confronted with the test set. The aim of this evaluation is to find out how well the nascent algorithm classifies images of crops or plant damages that are "unknown" to it. Since all utilized images have been manually labeled beforehand, it is now possible to draw a comparison between how the emerging algorithm classifies the test set and how FLORA's human experts have classified it beforehand, and to thereby determine its "accuracy."

However, as the computer scientist continued to explain, distributing pictures across the train and the test set is not that easy since an unthoughtful distribution can cause problems that

[25] In machine learning vernacular, the term "class" refers to different groups of things that a classification algorithm ought to classify.

reduce the performance of the prospective algorithms. The most important of these problems is known as “overfitting.” In a nutshell, computer scientists use the term overfitting to refer to situations in which an algorithm in development adjusts itself to visual patterns in the training data that are too specific and do not generalize to unknown data. Thus, a classical indicator of overfitting is that the classifications of a nascent algorithm are correct much more often when analyzing the training set than when analyzing the test set.

The computer scientist described several practices or rules through which he attempts to avoid overfitting. The first rule he mentioned was to never split the images uploaded by one user across the training and test set, provided that the respective user uploaded more than one image. As he put it, the reason for applying this rule is that if the images in the training set and the test set are too similar (e.g., shape of the leaf, lighting conditions, background details), the resulting algorithm will “memorize” these similarities, rather than classifying the depicted plant damage based on more universal visual patterns. Yet, the computer scientist also pointed out that applying this rule is “not as trivial” as it sounds, and that it requires some finesse, since users usually upload different amounts of pictures, which could throw the emerging datasets out of balance:

> “Then we distribute them into these buckets, train and test. This is also not so trivial, because if you say for example: Okay, we have the rule that pictures must not be separated from a user, right? And now you have a set, let’s say for white flies and you have pictures from two users, and one user gives you a thousand pictures [e.g., a picture hunter], another user gives you a hundred pictures, right? So now you want to apply a 1/3, 2/3 splitting. But you can’t do that if you want to consider this rule, because then you would have 100 versus 1000. […] So, that has to be balanced somehow.”

A second practice through which the computer scientist attempts to avoid overfitting and increase the diagnostic performance of PHYTØ’s algorithms is adding more data to the data sets. Although the computer scientist generally follows the above-mentioned rule of gathering at least 50 pictures before beginning with the work of shaping a new algorithm, there is no fixed number of pictures to be included in the respective datasets that could guarantee that overfitting does not occur. A general rule, however, is that more data yields better algorithms than less data. Besides merely requesting that more images be collected, the computer scientist has other means at his disposal to increase or diversify the data sets that he compiles for the shaping of new algorithms. One of these means is called “data augmentation.” Simply put, data augmentation means randomly rotating, enlarging, or adding color filters to the images of the training set in order to diversify it and thus increase the classificatory performance of the algorithms that are trained with it. Another means is the careful use of duplicates. More precisely, the computer scientist distinguishes between different types of duplicates, some of which he assigns higher importance and others lower importance when training new algorithms. As his next statement shows, in doing so he is guided less by fixed rules and more by experiential knowledge:

> "Well, there are these complete duplicates where the picture is one to one the same. Then there are cases where the user maybe moved the camera a centimeter or so. A person would probably say: 'Yes that's the same.' For a computer it is not the same, because not every pixel is the same. And there is also the case that the user, for example, walks around a plant, which means that you have different views and that is very useful […]. [But] these pictures should not be worth as much as, let's say, a picture that comes from some entirely different location. This means that when I calculate my accuracy afterwards, I say: Okay, I give less weight to these pictures."

As this quote vividly illustrates, the work of assembling datasets for the shaping of new algorithms requires a skilled estimation of which duplicates might increase the performance of PHYTØ's nascent algorithms more than others. Subsequently, the computer scientist translates this assessment into different "weights" assigned to the different duplicates, that is, into numerical values that determine how much or little the pixel values of the duplicates are to shape the numerical features of the emerging algorithm.

In short, my point is that the practice of preparing datasets constitutes a selection practice in that it defines the images whose visual patterns are translated into FLORA's becoming algorithms, and how much each of these images should weigh in this translation. As this subsection has shown, a careful distribution of images over the training set and the test set can increase the performance of nascent algorithms. Conversely, as little as one unfortunately chosen picture in one of the datasets can significantly affect the performance of emerging algorithms. It is this fragility of PHYTØ's nascent algorithms that explains the rigorous selection of the FLORA team across the previous layers.

2.5.2. Training algorithms

Compared to the preparation of data sets, the actual training of new algorithms represents a rather small fraction of the computer scientist's day-to-day work. As he put it, "this normal training that's relatively trivial but preparing datasets, that's quite tricky." One reason for this perceived triviality of training PHYTØ's algorithms is that in "transfer learning," that is, the type of machine learning method FLORA uses, developers take an algorithm that has been trained for a certain classification task (e.g., recognizing balloons) as a basis for a new algorithm meant to perform a different classification task (e.g., recognizing cars).

In the case of PHYTØ's image recognition algorithms, the algorithm of origin is an algorithm called "GoogLeNet" which has been developed by the Google scientists Szegedy et al. (2015)—an algorithm that is commonly used for image processing purposes in the realms of food and agriculture (cf., Saleem et al., 2019; Singla et al., 2016). In its development process GoogLeNet was trained on a freely available database called "ImageNet" containing more than 14 million hand-labelled images covering approximately 20,000 different classes (e.g., mushroom, umbrella, coffee mug). Given this pre-trained algorithm, FLORA's computer scientist explained that his task in training PHYTØ's algorithms would essentially consist of adapting GoogLeNet to FLORA's needs. As he explained it, image recognition algorithms are composed of different layers (not to be confused with the layers that form the analytical unit of this chapter), all of which are designed to recognize different visual "features," where the first layers are designed to recognize more general or "low-level features" (e.g., colors, edges, blobs) while the latter are meant to recognize more specific or "high-level features" (e.g., facial expressions, objects, animals). As he summed it up, in training he would simply "chop off" the last layer of the 22-layered GoogLeNet algorithm and replace it with a new layer that was attuned to the specific visual features of FLORA's image database.

As the computer scientist explained, this work of replacing the last layer begins, with the definition of the number of "epochs," that is, the number of times the becoming algorithm is supposed to analyze the relevant data sets (e.g., images of "fall armyworm" in "maize") in a training process. Then the computer scientist initiates the actual training process. During this analysis, the "weights" of the nascent algorithm, that is, its numerical features, change with each epoch in relation to the specificities of the analyzed dataset. The result of this process is a graph showing how the classificatory performance of the respective algorithm has changed in the course of the epochs. This classificatory performance can be expressed with various metrics. A common metric for this purpose is "accuracy," which is calculated by dividing the number of correct predictions by the total number of predictions.

Once a certain number of these trainings have been completed, the computer scientist evaluates their results. As he put it, "in the end you get an Excel sheet with accuracies for different disease-plant combinations." In evaluating the results listed in this Excel sheet, the computer scientist is in close exchange with the employees of the plant team. The way he explained it, "typically, this table goes to the plant experts, who look over it, to see if they notice anything that might be a mistake." An example of how such an error might manifest itself is that the plant team might find that the accuracy for a particular plant damage in a particular crop is very low, even though the computer scientist had calculated a higher one in a previous training. As he pointed out, he would usually correct such errors through "trial by error," that is by changing the dataset or the code of the algorithm while hoping "that it [the accuracy] gets better somehow." Lastly, "when the results are useful," he continued to explain, "I just have to switch them live."

Hence, training algorithms is a selection practice in that the computer scientist is required to determine whether FLORA's nascent algorithms are ready to be deployed or not. If the startup has worked meticulously throughout all the previous layers, the training results in a new algorithm capable of recognizing a particular plant damage in a particular crop with a high degree of accuracy. In case something went wrong on one of the previous layers, the computer scientist must work with the plant team to identify the source of error and see that it is corrected, before reinitiating training.

2.6. Representing results

The fifth layer in the construction of PHYTØ's algorithms consists of representing their classificatory results. The description of this layer is also based on the interview with the computer scientist that formed the basis of the previous subsection, and by two documents circulating within the startup. Unlike the previous subsections, this last empirical subsection describes only one selection practice which deals with displaying diagnoses.

2.6.1. Displaying diagnoses

Once the algorithms developed by the FLORA team are deployed in PHYTØ, the actual classification of incoming pictures is carried out by a server that the team of the startup refers to as "Peacock." Within Peacock, six different algorithms work together to generate PHYTØ's final diagnoses. In our interview, the computer scientist pointed out that when an image is uploaded by a user all these six algorithms (also referred to as "models" or "nets") operate simultaneously, with the analytical process taking "roughly a second." He illustrated this analytical process as follows:

> "Basically, these models give you answers to various questions. Disease net tells you which disease it is, crop net tells you: Tomato, potato, whatever, which plant variety it is. Object net tells you for example, it's a coffee cup, it's a cell phone, or whatever. Quality net can tell you for example that a picture is too blurred or that the distance to the plant is too far. One thing that often happens is for example: People take a picture of a rice field but only of the field and not of the actual plant, because it is just a bit impractical if they have to get into the wet field, so, they think: 'Ah that's enough.' But it's not enough and the quality net will tell such mistakes in the picture and then you can say later: 'Okay, because the quality net said the quality is too bad, we cannot trust the result of the disease net.' Then we have another net, the species net, which is quasi trained from external plant and animal pictures from the internet. So, there is this kind of Wikipedia for species […]."

Hence, besides the algorithms for the recognition of crops and plant damages (also referred to as "Crop Net" and "Disease Net") around which this chapter revolved, Peacock also comprises three additional algorithms that are trained to classify additional aspects of an uploaded image (namely the "Object Net," the "Quality Net," and the "Species Net"). Lastly, there is "Ferret," which results are ultimately displayed to users. As the computer scientist explained:

> "Then we have Ferret which is a kind of meta net that takes all the outputs from these nets and then decides what should come out in the app, right? And so, for example, one rule could be now, when quality net says, 'quality is too bad,' then tell the user, 'Okay take a new picture' or something. Or if, for example, the disease net is somehow uncertain, then it could say, 'okay we still give out the result of the crop net, but we will keep that from the disease net and just say: Okay you get a list of common diseases in your area for this plant instead of a wrong result.'"

For the outputs of Ferret, the FLORA team has defined different thresholds (probabilities) in relation to which PHYTØ's user interface displays diagnostic results differently. First, as can be inferred from the explanations of the computer scientist if the probability that Ferret calculates for a plant damage exceeds a certain threshold PHYTØ displays an unambiguous classification like, for example, "Potassium Deficiency." Second, if Ferret calculates a lower probability, PHYTØ's user interface shows a list of multiple plant damages and invites users to make the final classification by themselves. Third, there are situations in which PHYTØ displays an error message to its users, for example, when the "Object Net" calculates a particularly high probability for a given object like, for example, when a user uploaded a picture of a coffee cup for fun.

Overall, this way of displaying the classificatory results of PHYTØ minimizes the number of false positive diagnoses that are issued by the app, and thus reduces the potential damage that incorrect pesticide recommendations could cause on the part of users (e.g., financially) or their crops. At the same time, as a side effect so to speak, it is of course also a design decision that serves to maintain PHYTØ's user numbers by having the app always display some kind of result.

In summary, the decision on how to display diagnoses calculated through PHYTØ's algorithms too can be grasped as an important selection practice, as it determines which aspects of the diagnostic process are disclosed to users and which are not. As this subsection has shown, the FLORA team aims to keep the number of false positive diagnoses generated by PHYTØ low while providing users with workable outcomes (one plant damage diagnosed, multiple possible plant damage diagnosed, error). On the other hand, this way of presenting the results of PHYTØ does not inform users about ambiguities and uncertainties in how they were generated. In other words, from a user perspective, PHYTØ's diagnostic function is a classic example of a black-box as conceptualized by Latour (1999), in that the way it works "is made invisible by its own success" (p. 304).

Conclusion

This chapter has shown how the work that is required to make the algorithms deployed in PHYTØ automatically classify plant damages gradually inscribes a selective recognition of the phenomenon of plant pathology into the app. More specifically, the chapter identified five different "layers of knowledge production" (Bechmann & Bowker, 2019) that constitute the construction of PHYTØ's algorithms, namely defining problems, generating data, preparing data, shaping algorithms, and representing results. Based on this, it was argued that the developers of PHYTØ subject the phenomenon of plant pathology to different practices of "selection" (Lynch 1990) at each of these layers. As has been shown, this process is a double-edged affair: On the one hand, it enables PHYTØ to recognize a relatively large number of plant damages (currently 500) on a relatively large number of crops (currently 30) with a relatively high accuracy. On the other hand, it excludes other aspects of the phenomenon of plant pathology phenomenon from recognition. If one was to discern a pattern in these excluded aspects, one could say that they represent the "in-betweens" of plant pathology (e.g., rare crops, rare plant damages, crop varieties in general, severity of a plant damages on leaves, spread of a plant damages in fields). It is this double movement of making recognizable and excluding from recognition that the chapter has tried to capture with the term selective recognition.

Yet, what are the material consequences of PHYTØ's selective recognition of plant pathology? Based on the results of this chapter, I conclude that there is much to suggest that PHYTØ's automated image recognition, in its current manifestation, seems conducive to more pesticide-based ways of farming. This is because it is primarily less pesticide-based approaches to agriculture and crop protection (e.g., IPM, agroecology, organic farming) that depend on the above-mentioned in-betweens of plan pathology that are not recognized by PHYTØ's algorithms.

It is important to emphasize that the chapter does not infer that the developers of PHYTØ are intentionally and for dishonest motives incorporating a bias in favor of pesticide use into their app—an argument often found in generic newspaper articles or popular science papers on AI. Rather, the chapter should be understood as documenting a process through which an increased compatibility, which might be referred to as a bias in favor of pesticides, was gradually inscribed into an image processing device for agricultural purposes as a function of everyday design decisions, technical standards, and economic constraints.

These findings have important implications for the debates on agricultural big data and agricultural algorithms that served as the starting point for this chapter. First, the chapter substantiates Bronson and Knezevic's (2016) classic critique that agricultural big data leads to a strengthening of the dominant market position of Big Ag corporations. More specifically, it provides a detailed look into how such a strengthening may occur in the day-to-day practices of a big data-driven startup. As explained in the first chapter of this thesis, FLORA cooperates with large pesticide and input manufacturers in two ways, namely by renting out access to PHYTØ's algorithms and by charging commissions on pesticide sales brokered via PHYTØ's diagnoses. This chapter has described the nature of this cooperation in further detail. On a very concrete level, the chapter has shown the work that FLORA spares these corporations by freeing them from the work of developing their own image recognition algorithms. On a more abstract level, this chapter has argued that the type of diagnostic knowledge generated by PHYTØ's algorithms appears to be particularly conducive to agricultural practices that rely more heavily on chemical pesticides, a group of products that constitute the core sales of these companies.

This last point is closely intertwined with and adds to Carbonell's (2016) argument that most agricultural big data projects privilege knowledge that is focused on "inputs and production" (p.3) while refraining to produce knowledge about other objects like "industrial agriculture externalities and vulnerabilities" (ibid.). To put it plainly, the chapter has shown repeatedly how the selection practices carried out by the team of FLORA aim to ensure that PHYTØ generates unambiguous diagnoses, of isolated plant damages, on isolated crops. These unambiguous diagnoses are critical to PHYTØ's latest business model because they allow the startup to issue unambiguous pesticide recommendations. On the other hand, the unambiguity of PHYTØ's diagnoses comes at the cost of concealing the uncertainties and ambiguities that characterize the app's diagnostic process thus making it difficult to challenge or to hold the startup accountable for erroneous results.

Third, the chapter offers a slightly different account of what Fraser (2019) would refer to as "data grabbing." While the chapter agrees with Fraser that it is deeply worrying how companies from the Global North are accumulating data concerning agriculture in countries of the Global South to extract revenue, the chapter comes to a different conclusion as to how this accumulation occurs. More specifically, in the case of FLORA, the problem seemed to be less a problem of grabbing pre-existing data and more a problem of collectively producing new data. This was most evident in the work of FLORA's picture hunters, which, when read through the analytical lens of Denis and Goëta (2017), amounts to a construction of raw data. Hence, as this chapter has attempted to show, the differentiation between grabbing data in Global South agriculture and constructing data concerning Global South agriculture has important analytical implications. The former puts a stronger emphasis on the problem of data sovereignty whereas the latter puts a stronger emphasis on the more implicit problem of how both harmless and potentially harmful biases are inscribed into and reproduced by the respective datasets.

Fourth, the chapter resonates with Fairbairn and Kish's (2021) critique of the alleged "data deficit" that providers of big data technologies commonly attribute to farmers in Global South countries, as a justification to diffuse their technologies. As the authors put it the data deficit framing reveals "a knowledge politics that echoes the past" (p. 9) in that the increased vulnerability of farmers in Global South countries is presented as a result of insufficient knowledge, technology, or data analytics rather than "the structural residues of colonialism, agricultural intensification, and neoliberal development policies" (ibid.). While the present chapter has not made any explicit points about colonialism or neoliberalism, the selective recognition it has identified bears a strong resemblance to processes of rationalization in the course of agricultural intensification projects of the past. More to the point, one could argue that FLORA purports to address a supposed "data" or "knowledge deficit," while being oblivious to the fact that interventions like its own always create new knowledge deficits too, as, for example, with respect to the "in-betweens" of plant pathology specified above.

Besides the literature on agricultural big data, the chapter contributes to the small body of literature concerned with agricultural algorithms. First, the chapter refines Miles' (2019) argument that the truth claims that agricultural algorithms produce are exclusively rooted in a logic of capitalist production. More precisely, the results of the chapter coincide with Miles' argument insofar as they show that FLORA's construction of algorithms is shaped by economic interests (e.g., prioritizing crops in a way that maximizes user growth). However, contrary to him, the chapter suggests that the knowledge that agricultural algorithms produce is a co-product of such economic interests, technical requirements of algorithms (e.g., image quality), and human decision-making (e.g., considering some crops more important than others). In short, the chapter has shown that Miles' assertion that the truth claims of agricultural algorithms derive exclusively from capitalism does not adequately capture the everyday practices of assembling such algorithms.

Second, this chapter expands on Carolan's (2020) argument that agricultural algorithms lead to different "lock-in" effects such as the propagation of monocultures or the loss of local knowledge. To begin with, the term bias that I have used at times in this chapter is very close to the term lock-in which Carolan uses. However, following Jaton (2021b) the chapter has shown that it is important not to stop at identifying lock-in effects or biases, but to reconstruct the processes by which these biases are gradually inscribed into digital agriculture technologies. Yet, since all algorithms are based on biases (Jaton, 2021a), the goal of social science and humanities scholars working on digital agricultural technologies should not be to advocate for algorithms that are free of biases (or lock-ins), but to identify those practices in the construction of the corresponding algorithms that give rise to biases (or lock-ins) that are questionable. This chapter has done this by identifying layer by layer practices that result in PHYTØ's selective recognition of plant pathology—practices that could be partially modified by the developers if they wished to change the app's recognition.

3. Enacting expertise at a distance

Summary of the chapter in French (for formal reasons): 3. « Enacting » l'expertise à distance

Sur la base de l'affirmation fréquemment réitérée par FLORA selon laquelle l'application PHYTØ elle-même est un « expert numérique », le troisième chapitre explore comment la startup maintient cette revendication d'expertise à distance, c'est-à-dire depuis le back-office de la startup. Sur le plan théorique, le chapitre s'inspire de la recherche anthropologique sur le conseil agricole mobile (Stone, 2011) et soutient que les services de conseil agricole basés sur les smartphones, tels que PHYTØ, doivent être compris comme un « enactment » collective (Carr, 2010) de l'expertise. Plus précisément, le chapitre soutient que l'équipe FLORA a jusqu'à présent réussi à maintenir ce « enactment » d'expertise par le biais de PHYTØ en alignant constamment sa propre notion de conseil agricole adéquate sur la notion du conseil agricole adéquate de ses utilisateurs. En termes plus pratiques, le chapitre examine le travail de l'équipe chargée des questions relatives aux plantes, et identifie deux phases successives dans la manière dont ses employés inscrivent les services du conseil agricole dans l'application. Il montre que ces phases diffèrent dans la mesure où elles sont caractérisées à la fois par une forme et une conception différente du conseil d'expert : Dans la phase initiale du conseil agricole mobile de PHYTØ, l'équipe chargée des plantes s'est attachée à fournir aux utilisateurs des conseils textuels plus longs, imprégnés d'instructions relativement étroites sur la manière de cultiver. Cependant, FLORA a progressivement constaté que les utilisateurs de PHYTØ manifestaient peu d'intérêt pour ces textes. La conséquence en a été un changement dans l'approche de PHYTØ en matière de conseil mobile. En d'autres termes, l'intérêt limité des utilisateurs pour les conseils textuels de PHYTØ a marqué le début de la phase tardive des services du conseil agricole mobile de l'application. Dans cette phase, l'équipe des plantes a concentré ses efforts sur la fourniture aux utilisateurs d'une sélection de brèves recommandations de pesticides (biologiques et chimiques), sans être explicite sur les mesures de protection des cultures qu'elle jugeait les meilleures. Cette nouvelle conception des services de conseil mobiles de PHYTØ a capté l'intérêt des utilisateurs de PHYTØ plus efficacement que la précédente. Les instructions de PHYTØ sur la manière dont les utilisateurs doivent pratiquer l'agriculture sont ainsi devenues moins restrictives par rapport à la phase initiale. Sur la base de ces observations, et en s'inspirant de l'évaluation de Henke (2008) selon laquelle le conseil agricole en personne est une « technique fondamentalement conservatrice de changement social » (p. 146)—causée par l'inquiétude constante des agents du conseil agricole

concernant les agriculteurs qui leur refusent l'accès à leurs champs—le chapitre conclut que les services de conseil agricole mobiles comme PHYTØ pourraient bien être des techniques de changement social encore plus conservatrices.

Introduction

Recently, a growing number of agricultural extension apps have appeared in popular app stores that are claimed to be "agricultural experts." To clarify, while mobile extension services for feature phones are usually advertised as providing users with pre-existing expert advice, or connecting them with human specialists, an important novelty of extension services for smartphones is that the apps themselves are frequently said to hold agricultural expertise. To give an example, in public statements, PHYTØ, the app at the center of this dissertation, is variously referred to as "digital plant expert," "mobile crop doctor," "digital expert in your pocket," "crop doctor app," or "pocket agronomist." Such attributions of expertise are not exclusive to PHYTØ but are equally voiced with respect to other smartphone-based extension services. This chapter proposes to take these attributions of expertise at face value. In other words, it does not dismiss them as mere marketing talk but examines how the FLORA team sustains PHYTØ's claimed expert status through its everyday work in the back office of the startup.

To explore this question, the chapter combines three bodies of literature. First, the chapter mobilizes a loosely connected body of social science and humanities research that explores traditional agricultural extension, or in-person extension, from various perspectives (e.g., Cash, 2001; Henke, 2008; Jas, 2005; Le Velly & Goulet, 2015; Scott, 1998). Second, the chapter reviews a series of critiques of in-person extension, primarily written by development economists (e.g., Cole & Fernando, 2012; Fabregas et al., 2019; Ferroni & Zhou, 2012), to retrace the rise of mobile extension services from the late 2000s onward, to clarify the continuities between mobile extension and in-person extension, and to outline some of the practical problems posed by the former relative to the latter. Third, the chapter introduces two specific anthropological studies to develop its own conceptual approach towards mobile extension. On the one hand, a case study by Stone (2011) that provides a thick empirical account on the workings of a mobile extension service in India. On the other hand, a more theoretical article rooted in the anthropology of expertise that suggests to grasp expertise as a collective "enactment" (Carr, 2010), a proposal that provides the primary theoretical lens for this chapter. Drawing these two studies together, the chapter suggests to approach mobile extension as a collective enactment of expertise facilitated through mobile technology and formulates the following research question: How does FLORA's plant team, with the support of the start-up's software developers, sustain PHYTØ's enactment of expertise in their day-to-day work?

The main argument that the chapter develops in response to this question is that the respective employees have managed to sustain PHYTØ's enactment of expertise, for the time being, by continuously balancing their own notion of adequate mobile extension with users' notions of adequate mobile extension. More specifically, by examining the work of FLORA's plant team, the chapter identifies two successive phases in PHYTØ's provision of mobile extension services, each characterized by a different form of mobile extension and a different conception of expert advice. As will be shown, in the early phase of PHYTØ's mobile extension services, the developers focused their efforts on providing users with lengthier text-based advice, giving relatively prescriptive instructions of how they should farm. However, the FLORA team gradually came to realize that PHYTØ users showed little interested in these texts. As a consequence, the FLORA team redesigned PHYTØ's mobile extension service which ushered in the late phase in PHYTØ's mobile extension services. In this phase the plant team focused its efforts more on providing users with a selection of brief pesticide recommendations (both biological and chemical), while not being explicit about which of the suggested crop protection measures they deemed best—a form of mobile extension that captured the interest of PHYTØ users more effectively than the previous one. The chapter thus demonstrates how FLORA has managed to sustain PHYTØ's enactment of expertise by gradually shifting from a more prescriptive conception of mobile extension to a less-prescriptive conception of mobile extension. On a more general note, the chapter develops the argument that providing agricultural expert advice via a mobile app is not a one-time-achievement but a constant balancing act, a back and forth, between what developers and users of such services consider to be adequate extension. It is this technologically mediated negotiation of what constitutes adequate mobile extension and what does not that this chapter refers to as PHYTØ's collective enactment of agricultural expertise.

This argument is developed over the course of three sections: Section one is a theoretical section that introduces the problem of the chapter more thoroughly by reviewing existing research on in-person extension and mobile extension, before highlighting the analytical interest in examining mobile extension as an enactment of expertise. The remaining two sections are empirical sections that explore how the FLORA team sustains PHYTØ's enactment of expertise through their day-to-day work in the back office of the startup. Section two scrutinizes the early advisory text-centered phase of PHYTØ's mobile extension services, and how the developers slowly came to realize that users had little interest in these texts. Consequently, section three revolves around the late pesticide recommendation-centered phase of PHYTØ's mobile extension services. The chapter closes with a conclusion that summarizes its main findings and their meaning for the larger ensemble of the dissertation.

3.1. Sustaining a mobile extension app's enactment expertise

3.1.1. Different collectives of in-person extension

In order to approach the phenomenon of mobile extension analytically, it is important to comprehend its origins in classical extension, that is, in-person extension. Social science and humanities scholars have examined in-person extension in different forms and from different angles and concur that it is much more than simply a linear transfer of knowledge from science to farmers mediated by extension agents. Rather, these scholars point out—some explicitly, others more implicitly—the success or failure of in-person extension hinges on a complex interplay of humans (e.g., extension agents, farmers, scientists) and non-humans (e.g., plants, animals, soils, chemicals, maps, test kits, didactic instruments) that converge in agricultural settings. This first subsection examines a selection of these studies to provide a more detailed impression of this collective character of in-person extension.

An insightful study to shed light on the beginnings of in-person extension is Jas' (2005) historical analysis of the emergence of agricultural science in France between 1840 and 1914. The primary argument that Jas develops in this study is that the emergence of this new type of science, and its profound transformation of French agriculture, can be attributed to a specific mobilizing discourse, whose origins she traces to the chemist Louis Grandeau—a discourse that, according to Jas "disqualified"[26] the peasant and "enthroned" the agronomist, and thus laid the foundation for the modernist agriculture of the centuries to come. To elaborate a bit more, Jas begins her analysis by showing how Grandeau imported the organizational form of the agricultural experiment station from Prussia and Saxony to France—an organizational form characterized, in short, by the combination of chemical laboratory science and efforts undertaken in the field to attach farmers to scientifically proven chemical products. Thus,

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[26] All quotations from this article are my translation.

agricultural experiment station can be seen as a precursor to many of today's extension organizations. As Jas goes on to demonstrate Grandeau succeeded in establishing agricultural experiment stations in France, through a mobilizing discourse that was based on four pillars. The first pillar that Jas identifies is "the establishment of an absolute link between the agronomic station and national prosperity" (p. 49). The second pillar Jas highlights is "superiority given to the laboratory" (p. ibid.), by which she means that the laboratory became the fundamental distinction mark between agricultural scientist and agricultural practitioners, a boundary separating specialists from lay people. Third, Jas underlines "the construction of a double image of the peasant" (p. 50). On the one hand, a small group of farmers "already engaged in a capitalist and 'modern' agriculture, symbolized at that time by the use of so-called industrial fertilizers" (ibid.). On the other hand, what was framed as "an ignorant, naive and even stupid mass" (ibid.) marked by their non-use of the aforementioned fertilizers. The fourth pillar of the discourse identified by Jas builds on this double image of the peasant and consists in a call for "the transformation of this mass of [ignorant] 'cultivators' into model farmers, 'intelligent', converted at once to capitalism and science" (p. 51). This discourse, Jas concludes, served its purpose in that it materialized in a proliferation of new agricultural experiment stations in France, laws to protect the allegedly ignorant farmers, agricultural unions who also took up the cause of educating peasants, and, as a result of all this, a drastic shift in the agricultural practices of French farmers towards more intensive, capitalist, science-oriented modes of action that continue to this day.

Another important analysis on early in-person extension comes from political scientist and cultural anthropologist Scott (1998). Taking a historical look at different public extension projects throughout the 20th century, Scott characterizes the phenomenon of agricultural extension as a "high-modernist" (p. 4) intervention. More specifically, he ranks agricultural extension among a number of other such interventions like the introduction of scientific forestry in Prussia, urban reforms in Brazil and India, and forced villagization projects in Tanzania. As Scott argues, the common ground among these projects is that they all aim to make society and nature "legible" (p. 2), that is, amenable for state control. In the case of agricultural extension this creation of legibility proceeded primarily through a "radical simplification" (p. 262) of the rural environments into which the state agricultural extension agents intervened. On the one hand, Scott describes that this simplification led to a dramatic maximization of productivity and profits. On the other hand, he also sees it as the reason why the project of agricultural extension in the 20th century failed:

> "The simple 'production and profit' model of agricultural extension and agricultural research has failed in important ways to represent the complex, supple, negotiated objectives of real farmers and their communities. That model has also failed to represent the space in which farmers plant crops—its microclimates, its moisture and water movement, its microrelief, and its local biotic history. Unable to effectively represent the profusion and complexity of real farms and real fields, high-modernist agriculture has often succeeded in radically simplifying those farms and fields so they can be more directly apprehended, controlled and managed" (p. 262).

In short, Scott argues that agricultural extension is a deeply rationalistic endeavor that does not do justice to the complex realities of agriculture on the ground. Throughout his text, Scott cites numerous examples to support this argument. Among other things, he discusses the drastic reduction in the number of crop varieties cultivated worldwide that was induced by agricultural extension systems. Another example he invokes is how, extension agents conducted campaigns in colonized African countries in order to replace polycultures that have been cultivated for centuries by indigenous populations with monocultures supported by foreign scientists. Lastly, he cites the example of agronomic models of yield prediction and how they reduce complex agroecosystems to a few isolable variables. In short, in Scott's analysis, agricultural extension is seen as a tool through which authoritarian states exert control over rural populations and the natural world, wherein, inspired by Foucault (1978), he puts a lot of emphasis on the technologies and devices, that is, the non-humans, through which this control is executed.

In a similar vein, yet generally less critical of in-person extension, STS-inspired public policy scholar Cash (2001) provides an extensive analysis of the U.S. Cooperative State Research, Education, and Extension Service (CSREES). Drawing on a concept coined by Guston (1999), Cash argues that the CSREES, and agricultural extension organizations more generally, should be thought of as "boundary organizations" that "mediate between the shifting domains of science and policy" (Cash, 2001, p. 431). To flesh out this argument, Cash presents a detailed case study concerned with an agriculture-related water conservation project conducted by the CSREES. Cash cites several examples of how the agricultural extension agents affiliated with the CSREES act as mediator between scientific researchers and users of technical and scientific information (i.e., farmers). First, he mentions how extension agents "facilitate dialogue between farmers and scientists to encourage research agendas that reflect the interests and needs of farmers" (p. 440). Second, he describes how extension agents "translate scientific information produced at land-grant colleges, putting general findings into site-specific language and guidance" (ibid.). Thirdly, he points out how extension agents "manage demonstration projects and field applications that integrate farmers into researchers field experiments" (ibid.). These examples illustrate another point that is of great importance in Cash's analysis, namely that the extension agents of the CSREES are accountable to both sides of the boundary, trying to harmonize the interests of scientists and farmers. In summary, then, Cash points to the reciprocal nature of agricultural extension. He shares Scott's (1998) attention to the material conditions of in-person extension but paints a very different picture with respect to the ways in which agricultural extension agents advance their interests. More specifically, while the extension agents described by Scott enforce their interests or those of the state through more authoritarian control mechanisms, the extension agents in Cash's study do so through tools and procedures based on a mutual exchange of ideas with farmers.

Sociologist and STS scholar Henke (2008) offers a similar, yet again slightly different, account of agricultural extension. In a comprehensive ethnography of extension agents in a specific Californian valley specialized in large-scale lettuce farming, Henke develops the argument that agricultural extension should be grasped as a form of "repair work" (p. 7). To explain what he means by this: Henke conceptualizes industrial agriculture as an "ecology of power" (p. 6) which he specifies as "a broad system of social and material production where growers and agricultural scientists turn products created from local contexts—food, commodities, data, knowledge—into capital" (ibid.). The problem with this heterogenous ecology, Henke goes on to argue, is that it is regularly disrupted for diverse reasons, be they extreme weather events, spontaneous pest outbreaks, governmental regulations, or budgetary crises. Whenever such disruptions occur the agricultural extension agents he studied come into play "maintaining this system in the face of constant change" (p. 10), that is, performing repair work to keep the productivist agricultural system in which they operate running.

Yet, compared to the two previous accounts on agricultural extension, the extension agents studied by Henke are less influential in actually changing the behavior of farmers. An illustrative example that Henke provides to underline this point is a case in which the extension agents attempted to persuade farmers to apply less fertilizer by using a newly developed "quick test" to monitor the nitrate levels in their soils before applying additional nitrogen fertilizer. As the extension agents had originally envisioned, this solution would not only help reduce nitrate leaching into the groundwater, but also offer farmers a small monetary incentive since they would have to spend less money on unnecessarily applied fertilizer. However, farmers did not adopt the quick test as well as the extension agents had anticipated. For Henke, this was because the farmers in question had a different perception of environmental problems, a strong attachment to their standardized fertilization methods, and because the economic incentive was too small. However, since the extension agents in Henke's study had to be careful not to spoil their relationship with farmers, they had to accept the fact that farmers continued to overfertilize as they had. Based on examples like this, Henke draws the conclusion that agricultural extension is a "fundamentally conservative technique of social change" (p. 146). In short, then, similar to Cash, Henke portrays agricultural extension as a collaboration between extension agents and farmers, in which varying materials (e.g., soils, nitrates, "quick tests") play an important role. However, other than in the case described by Cash, the tie between extension agents and farmers that Henke describes is much more fragile, which influences the agency of the consultants relative to the farmers making their interventions more "conservative."

Another important perspective on the object of agricultural extension is provided by sociologists and STS scholars Le Velly and Goulet (2015) who grasp extension as a process of establishing commercial attachments. While Scott, Cash, and Henke all scrutinize public extension efforts, Le Velly and Goulet shift the attention to extension services that are provided by private companies. Empirically, the researchers examine the case of a French farm supply company selling a specific fertilizer which, as they describe it, is controversial from a scientific point of view because it does not contain phosphorus—a mineral that, along with nitrogen and potassium, is a core ingredient of most commercial fertilizers. The company's atypical stance towards phosphorous is not only criticized by scientists, but also by competitors and other farmers, who frame the company's products as ineffective and even dangerous. Despite this controversy, the company flourishes economically which Le Velly and Goulet attribute to the work of its commercial extension agents.

According to the authors, the work of these sales representatives comprises five distinct mechanisms: The first mechanism consists of "[d]etaching farmers from phosphorus, science and its institutions" (p. 8) by developing a number of counter arguments. The second mechanism involves a "[d]etachment from other input suppliers" (p. 10) by foregrounding their 'purely economic' interests. With the third mechanism, the "[s]ingularization of the relationship with the product through advice" (p. 12) the authors refer to the fact that each visit of the company's extension agents to a farmer is accompanied by a comprehensive tour across the farm "to determine the condition of the plants, soil and animals, and consider what action needs to be taken" (pp. 12-13). Fourthly, Le Velly and Goulet observe how the sales representatives attach farmers "to new crop practices and new natural entities" (p. 14). In the case they study, these are primarily no-till practices and entities that benefit from them, such as earthworms. As a fifth and final mechanism, the authors highlight that when the attachment is complete "[a] community of values between sellers and customers" (p. 15) forms. To recap, Le Velly and Goulet provide a vivid account of a functioning agricultural extension service or collective in the private sector. The study is not to be misunderstood as a critique of commercial extension efforts. Rather, the authors aim to show that the company's extension agents manage to sell the respective fertilizer, despite its controversial composition, exactly because they are careful providers of other extension services. In other words, Le Velly and Goulet show that the services of the commercial extension agents make the value of the fertilizer in question.

In sum, all of these studies show that in-person extension is a process that requires a great deal of time, money, labor, and other resources, while success is never guaranteed. Against this backdrop, as soon as mobile phones became more widespread in rural areas around the world, many scientists, politicians, and entrepreneurs increasingly looked to these technologies as a means of overhauling the realm of in-person extension.

3.1.2. The rise of mobile extension and some of its failures

The group of scholars who have so far been most concerned with mobile extension are agricultural and development economists. For the purposes of this chapter, these studies serve as an entry point into the phenomenon of mobile extension and some of the practical issues it raises. As these researchers document, beginning around the mid-2000s, an increasing number of mobile extension services, that is, agricultural extension services based on cell phones, were being developed and made available to farmers—a trend that went hand in hand with the increasing privatization of the agricultural extension sector around the world (Benson & Jafry, 2013). In other words, while there were some public sector actors developing mobile extension services, the trend was dominated by private sector actors hoping to tap new markets by means of mobile technologies. Against this background, especially with regard to Global South countries, where the in-person extension sector was less established, mobile extension was expected to have great positive effects on yields, profits, or farmers' general well-being (Saravanan, 2010, 2014). The case of Nokia Life, briefly touched upon in the introduction to this dissertation, is a prominent example of such mobile extension projects. However, the era witnessed many other, smaller projects with comparable ambitions (Cole & Fernando, 2012).

In the analyses of economists, mobile extension is typically presented as a technological solution to problems of efficiency and expertise in the realm of in-person extension. In an article concerned with the "achievements and challenges in agricultural extension in India," for example, agricultural economists Ferroni and Zhou (2012) summarize the state of the country's in-person extension as follows:

> "Delivering extension well is difficult. Widely dispersed farmers can be hard to reach, and their information needs vary considerably. Larger farmers may benefit disproportionately. Budgets of extension agencies may be inadequate. There are often too few agents, and they may face problems with motivation, competence, performance, and accountability" (p. 320).

To pick out a few points, the scholars note that Indian farmers are "hard to reach," by which they mean that they are geographically dispersed and are therefore difficult to meet in-person for extension agents, which is further complicated by the fact that there "are often too few agents." Moreover, Ferroni and Zhou criticize, these extension agents do not always succeed in passing on the knowledge that the authors deem appropriate, either because they would be unable to satisfy farmers' variable "information needs" or simply because they would not have enough "motivation," "competence," "performance," or "accountability." As the authors go on to argue, one of the solutions to these multiple problems would be an increased provision of mobile extension services both from public and from private providers. As the authors go on to specify, "[m]obile applications can serve many needs" such as "extension in the narrow sense of advice, as well as input, services and output transactions, and data collection" (p. 335).

Despite this enthusiasm for these early manifestations of mobile extension services, many of them did not live up to the expectations they had originally raised, which often resulted in the projects being discontinued (Baumüller, 2017). However, with the advent of smartphones and the new opportunities they offered for the development of digital services, the phenomenon of mobile extension has gained new momentum. In a Science article Fabregas, Schillbach, and recent Nobel Laureate Kremer (2019), for example, review existing research on mobile extension and present an optimistic outlook:

> "Mobile phones can benefit farmers in low- and middle-income countries by improving access to agricultural advice and market price information. Mobile technologies, particularly smartphones, have the potential to bring sophisticated science-based agricultural advice to smallholder farmers to improve productivity, especially under rapidly changing economic and environmental conditions" (p. 1).

As examples of such smartphone-based advice, they cite that "[s]martphones with GPS systems create the potential for larger gains through the transmission of more sophisticated media, such as videos" as well as "for locally customized information on soil characteristics, weather, and pest outbreaks, delivered at the appropriate time during the agricultural season" (ibid.). Furthermore, they point out that "[m]essages could be customized on the basis of farmer characteristics, such as education or financial circumstances" (ibid.), or that "experimentation, machine learning, and two-way communication with and between farmers could facilitate improvements of information and other services over time" (ibid.). Lastly, they stress that "[a]dvances from behavioral science can improve information transmission and address behavioral barriers to the adoption of improved agricultural techniques" (ibid.). In short, the authors argue that smartphone technology can greatly improve the quality of mobile extension by allowing the information presented to be more specifically tailored to users' needs than any other mobile technology ever could—an assessment shared by many of their peers (Cole & Fernando, 2020; Fu & Akter, 2016; Mendes et al., 2020).

Nonetheless, despite this overall endorsement of mobile extension, the authors are reluctant to overgeneralize their assessment. This is because they see the success of mobile extension threatened by a range of problems they refer to as "market failures." To put it in the words of the authors: "Multiple market failures associated with information markets limit the ability of mobile phone–based extension systems to reach socially efficient scale through purely commercial financing" (Fabregas et al., 2019, p. 1). To understand what they mean by this, it is worth taking a look at the examples that the authors provide for such market failures both with regard to private sector projects and with regard to public sector projects. With regard to the private sector, the authors describe how several companies they analyzed tried to fund themselves through subscription models. The market failure that the authors observe with regard to such companies is that most farmers do not have the money or "willingness to pay" for such subscription-based services. Secondly, the authors predict that other private providers of mobile extension services—comparable to what FLORA does—might try to finance themselves through advertising or the sale of agricultural inputs. In this case, the authors see the market failure in the circumstance that such business models could "incentivize providers to distort information content in the absence of strong reputational costs of misinformation or appropriate regulation" (ibid.). In other words, the authors assume that in such cases, the extension services might be "biased" (p. 7). With regard to the public sector, the authors give the example that mobile extension services that are offered by agricultural ministries are often overly technical and therefore difficult to understand. The market failure that the authors report in this case is that farmers do not find the information that is to be conveyed to them helpful.

Taken together with the other studies presented in this subsection, these findings point to an interesting conundrum. More specifically, they highlight that even if there is great political, economic, and scientific interest to develop mobile extension services—so as to reform the much-criticized realm of in-person extension—the practical implementation of such services generally evokes problems that were not anticipated by the advocates of these technologies. It is possible to refer to these problems as market failures. Yet from an STS perspective, it seems more fruitful to view them as problems arising from an oversimplified understanding of how the mediation of knowledge, or the enactment of expertise, via digital technologies occurs.

3.1.3. The problem of enacting agricultural expertise via mobile technology

Development economists are not the only group of scholars who have studied mobile extension services extensively; cultural anthropologists such as Stone (2011) have also explored the phenomenon putting it in a slightly different light.

Stone's study is seminal to the problem of this chapter because it examines a project that is in many ways very similar to FLORA. This project, called "e-Sagu," was launched in 2004 by a computer science professor in the Indian state of Andhra Pradesh. As Stone points out, the project emerged in response to a tragic wave of suicides committed by cotton farmers in a particular district of Andhra Pradesh (Warangal). The e-Sagu team and other voices in the public debate attributed these suicides mainly to an alleged knowledge deficit on the part of farmers which they deemed to result from a poorly functioning agricultural extension sector. As a consequence, the team of the project came up with the idea to counter the supposed knowledge deficit by leveraging ICT technologies to provide farmers with expert advice. As Stone makes clear, the idea of providing farmers with information via ICTs was nothing new even then. For example, there had already been mobile extension services in India that provided farmers with pre-existing information about market prices or the weather before e-Sagu. The novelty of e-Sagu, however, was that the team had made it its mission to generate "customized advice for farmers" (p. 764), which the project team interpreted as using ICTs to provide farmers with advice generated by specialized employees based on data that was collected on the farmers' fields. As Stone puts it:

> "What distinguished e-Sagu [from other mobile extension projects in India] was its plan to take connectivity the next step, linking the farmer not just to information on the Internet but to agricultural experts telling individual farmers how to farm. Its basic conception, which resonated richly across a range of stakeholders, was that farmers were foundering for lack of

> access to guidance from agricultural scientists; forging this connection was a technical challenge, to be solved by ICT" (p. 762).

In practice, this meant that members of the e-Sagu staff, known as "coordinators," collected data in the fields of participating farmers, which were then fed into a central database in a laboratory in the city of Hyderabad. Subsequently, e-Sagu's agricultural specialists (plant pathologists, entomologists, extension scientists, etc.) analyzed this data in order to generate appropriate advice, which they uploaded to a website. Via this website, the coordinators, which were based in the vicinity of the farmers, could access the advice, and communicate it with the participating farmers. Nevertheless, the e-Sagu team quickly ran into a problem. Simply put, the farmers were not interested in the advice generated by the project's experts. This was not necessarily because the knowledge these experts provided was incorrect, but rather because it was presented or performed in a way that did not match the farmers' expectations regarding adequate extension.

As Stone argues, this was because in its beginnings the e-Sagu project "was unwittingly based on an extreme acultural model of external scientific expertise" (p. 781). This argument originates from Stone's perception of agricultural extension as an inter-personal process of "agricultural skilling" (Stone, 2007), by which he means that "the invention and adoption of agro-scientific knowledge is deeply embedded in daily productive activities and sociocultural interactions" (pp. 759-760). Another characteristic of skilling that Stone emphasizes is that it is a hybrid process in that it "combines ideas from off-farm (often institutional) sources with those generated and manipulated by the local community" (p. 771). As Stone argues, the e-Sagu project initially followed a diametrically opposed concept of agricultural extension that revolved around the idea of "delivering external scientific expertise" (p. 762) or "offering 'scientific' expertise ostensibly decoupled from the social dynamics of skilling" (p. 772). In other words, Stone argues that, in the beginning, the specialists working in the offices of the e-Sagu project were too concerned with providing the participating farmers with knowledge generated by off-farm scientific sources, and too unconcerned with the ideas of the local farming communities they sought to serve. The result of this was that initially no skilling took place, meaning that the local communities did not take the well-meaning advice of the e-Sagu team to heart.

According to Stone, after some time the e-Sagu team became conscious of this problem and began to "train its own experts" (p. 775) to rectify it. The goal of these trainings was to provide e-Sagu's employees, who had previously dealt with agriculture primarily from an academic perspective, with guidance on how to actually engage with farmers, listen to them, and communicate their advice in a way that was more adapted to their practical problems. These trainings, Stone continues, were a success in that they resulted in the e-Sagu employees and the farmers entering into a collaborative skilling process, in which the e-Sagu employees learned how to incorporate the practical concerns of farmers into the creation of advice, and the farmers eventually came to accept their suggestions as expert advice. Against the backdrop of this change of events, Stone draws the conclusion that the belated success of e-Sagu team resulted from an inversion of the project's underlying concept of expertise. As he puts it, "[i]n the case of e-Sagu, 'agricultural experts' came to understand that agricultural decision making had a substantial sociocultural component that required them to adopt local practices to have local credibility" (p. 779).

To wrap it up, Stone's study demonstrates that in the realm of mobile extension, expertise is anything but self-evident. Rather, in the provision of mobile extension services, expertise is a fragile achievement. Moreover, Stone's study makes clear that expertise in mobile extension and beyond has little to do with embodied knowledge of selected individuals. Instead, it is a collective achievement involving many different actors. Although Stone does not explicitly draw this connection, this perspective coincides neatly with a study by Carr (2010), an anthropologist of expertise, arguing that expertise should be first and foremost regarded as a collective "enactment" (Carr, 2010). This theoretical proposition provides the primary theoretical foundation for this chapter.

As Carr explains with reference to Collins and Evans' sociology of expertise (2009; 2002), research that approaches expertise as an enactment is usually based on "the simple premise that expertise is something people do rather than something people have or hold" (Carr, 2010, p. 18). Applied to the example of the e-Sagu project: despite their scientific credentials, the recommendations of e-Sagu employees were not considered expert advice by farmers until these employees took the time to meet these farmers and learn how to collaborate with them on a face-to-face level. Conceptualizing expertise as an enactment means to conceive of it as "inherently interactional" (ibid.) by which she means that it always involves "the participation of objects, producers, and consumers of knowledge" (ibid.), or as I put it, it means to conceive of it as collective achievement. This argument, too, is reflected in the case of e-Sagu, in which expert advice emerged in an interplay of ICT devices, coordinators in the field, back office specialists, educational materials, and farmers, to name but a few components. However, this emphasis on the interactive nature of expertise is not meant to say that the disciplinary training of e-Sagu staff in plant pathology, entomology, or extension science had nothing to do with the successful enactment of expertise at the later stage of the project. On the contrary, as Carr emphasizes, "[e]xpertise is also always ideological because it is implicated in semistable hierarchies of value that authorize particular ways of seeing and speaking as expert" (p. 18). In the realm of agriculture, these ways of seeing and speaking are commonly associated with disciplines such as plant pathology, entomology, or extension sciences. In light of these considerations, Carr emphasizes the methodological principle that, when viewed as an enactment, expertise should be studied as "a process of becoming rather than a crystallized state of being or knowing" (p. 19). Keeping these theoretical considerations and the example of e-Sagu in mind, the present chapter approaches PHYTØ's enactment of expertise as "a process of becoming" by asking the following question: How does FLORA's plant team, with the support of the start-up's software developers, sustain PHYTØ's enactment of expertise in their day-to-day work?

3.2. Early phase: Enacting expertise through advisory texts

In the early phase of PHYTØ's mobile extension services the app's enactment of expertise proceeded through the display of lengthier advisory texts regarding crops, plant damages, pesticides, and improved cultivation methods. This first section of the chapter examines the work through which the members of the FLORA team produced these texts in the back office of the startup. Empirically, the section is based on interviews with five (past and present) members of FLORA's plant team, a group of specialized workers with various plant-related disciplinary backgrounds (e.g., agronomy, plant physiology, plant pathology). Furthermore, the section is informed by three interviews with members of the FLORA team who supported the work of the plant team over the years (software developers, co-founders), as well as supplementary document analyses. As the section will show, FLORA's creation of advisory texts derived from the assumption of a relatively general knowledge deficit on the part of Indian farmers and unfolded through the creation of content for two slightly different features.

3.2.1. The problem of a general knowledge deficit

PHYTØ's advisory texts are to be understood as a response to the assumption of a relatively general knowledge deficit on the part of small-scale farmers in Global South countries, and Indian farmers in specific. At this point, an important parallel can be drawn between the present chapter and the discourse described by Jas (2005). This parallel consists in what Jas calls "the construction of a double image of the peasant" (p. 50). Similar to the discourse described by

Jas, this subsection shows how FLORA often paints the picture of being confronted with a large mass of mostly ignorant farmers, and how this framing serves the startup as a rationale for developing and circulating their mobile extension service targeted at Indian agriculture.

A vivid example of how members of the FLORA team used to problematize the knowledge or non-knowledge of farmers in the early phase of PHYTØ's mobile extension services is provided in a 2019 interview between a reporter of an agricultural news website and one of the co-founders of FLORA. In said interview, the co-founder described the perceived knowledge deficit of farmers quite candidly. As he puts it: "We recognized that there is a huge lack of agricultural advisory, especially for small and medium-holder farmers." However, the co-founder went on to explain, he and the rest of his team also realized that "all information about pests and diseases they [farmers] would need is actually available on the internet." The co-founder thus portrayed the solution to the supposed ignorance of farmers as a process of redistributing already existing knowledge—a consideration that, as will become clearer, figured greatly in PHYTØ's text-based extension services at the time.

A similar insightful description of the assumed knowledge deficit of farmers can be found in the subsequent quote, retrieved from an interview, in which a member of the plant team describes the state of extension services in India and the consequences of this state for Indian farmers:

> "So, I think, in India it's one extension agent for 10.000 farmers, something like that. You could ask other people, something like that number. It is actually absent, extension. You can see some kind of fundamental research going on, at some Indian universities, […] but there is no funnel to distribute this knowledge to the farmers, and because of the lack of this funnel the farmers stay undeveloped."

This quote is insightful because it contains another important assumption that echoes the plant team's approach in developing PHYTØ's early text-based extension services, namely, the assumption that agricultural extension operates as a "funnel" that translates knowledge unidirectionally from scientific institutions to farmers.

A final example of how members of the FLORA team used to describe the assumed knowledge deficit of farmers in countries of the Global South, and PHYTØ's capacity to address it, in the early phase of the app's mobile extension services is provided in an excerpt from a video of a presentation given by one of FLORA's co-founders in 2019 at an "AI summit" organized by a major German insurance company:

> "When we look to the Western parts of the world, Europe, and America, we have, in terms of production, really reached the limit but when we look to other countries on the African continent or on the Asian continent, we figure out that there is a high potential to increase the yields. So, what keeps these people back is really an access to appropriate knowledge."

As in the previous quote, the perceived knowledge deficit of farmers in countries of the Global South is used to explain FLORA's intervention into the agricultural systems of these countries. In addition, the quote is instructive in that it captures the FLORA team's ambition of providing farmers access to "appropriate knowledge," reflecting the assumption that making 'the right' knowledge available to farmers in Africa and Asia could go a long way toward equalizing their productivity with that of farmers in the US or the EU.

The simple point that this list of examples is meant to convey is that the FLORA team's assumptions about the knowledge or non-knowledge of farmers in the early phase of PHYTØ's mobile extension services played an important role in how these services were actually designed—a point that will be further substantiated in the following subsections.

3.2.2. Creating Encyclopedia content

The first important feature that the FLORA team developed to provide users with text-based extension services is the so-called "Encyclopedia." This subsection reconstructs the plant team's work on this feature. In doing so, the subsection shows that while the Encyclopedia has evolved over time in terms of content volume, professionalism, and infrastructure, its underlying concept of mobile extension as a unidirectional transfer of knowledge from science to farmers has remained relatively unchanged since its inception.

In a nutshell, the Encyclopedia is a feature that provides PHYTØ users with informational texts regarding common plant damages and how to treat or prevent them. Additionally, each Encyclopedia entry is equipped with photos that illustrate the corresponding symptoms in a variety of expressions. As briefly mentioned in chapter one, the Encyclopedia emerged from the idea to operate PHYTØ as a "crowdsourcing science" project. To recap, in 2015, when FLORA's image database was still small, the developers of PHYTØ were looking for a service they could offer amateur gardeners in exchange for images of their diseased plants and eventually came up with the idea of a digital encyclopedia. As can be inferred from the following quote from the co-founder, who was primarily responsible for the work on the Encyclopedia at the time, the creation of the respective content was a fairly straightforward affair:

> “So, we needed this library and then I just said: Okay cool, I have these books here now, I can write this together. [...] So I sat down there, started a document, which was actually a Google Drive. It said: ‘headline,’ I mean that was still in German, ‘Überschrift’ and then a little explanation of the thing and then just the treatments for it and we just wrote them all down in a document as simple as that. That was the first thing and slowly we built that into the app.”

What is interesting about this quote is that the interviewee made no secret of the fact that he himself had little expertise with regard to plant pathology when he started to work on the Encyclopedia, but simply copied the required expert advice from scientific books into the app. A very similar account of the early work on the content of the Encyclopedia came up in an interview with another co-founder who was supporting the work on the feature at the time:

> “It was a Google document that at some point, I don’t know, was 200 pages long and super lame, crazy. It crashed again and again because it was so full. That’s practically the Encyclopedia with all these disease entries.”

Taking the two previous quotes together, the statements of the co-founders bear a strong resemblance to Stone’s (2011) description of the early stages of the e-Sagu project in that mobile extension is grasped as a process of providing farmers in a one-sided manner with knowledge that is decoupled from, as Stone calls it, interpersonal acts of “skilling.”

Over time, the plant team professionalized the creation of Encyclopedia content, meaning that around 2017 the startup hired an employee with a PhD degree in plant physiology, who checked the already existing content for its scientific robustness. In addition, this new employee guided other less specialized employees in creating new content. On a slide from an internal presentation, members of this expanded plant team explained how they structured the individual Encyclopedia entries to the rest of the FLORA team. As they explained, the plant team divided each Encyclopedia entry into six different sections corresponding to their display in the user interface of PHYTØ, namely, “Nutshell,” “Symptoms,” “Trigger,” “Biological Control,” “Chemical Control,” and “Preventive Measures.” Subsequently, they filled these categories with information that was already in FLORA’s database or copied and condensed new information from external sources into the corresponding text fields. In short, the slide illustrates that the general method of the plant team to create Encyclopedia content has remained relatively unchanged since the inception of the feature, insofar as the plant team continued to transfer pre-existing knowledge from external sources into the app. By the time of the presentation, the plant team had already created 300 Encyclopedia entries through this approach.

In this endeavor, they were also supported by a steadily improving information infrastructure. More precisely, over time FLORA's software developers had programmed a so-called "content management system" which enabled the plant team, even without computer scientific know-how, to write, review, and deploy Encyclopedia entries in the app. In an interview, one of the software developers of the startup summarized the composition of this system by describing its three major components—a database, a front-end, and a back-end—as follows:

> "It's a technical construct of at least three components. The content should end up in a database, so you need a database. People need to be able to enter the content. That's the front-end, that's what users [the plant team] see in the browser. And the content must undergo some kind of transformation. So, it has to be validated: 'Is this now a correct input option for this data field? Is it allowed to be a number here or should it be something else?' [...] And these dependencies are solved in the backend and then, as I said, stored in the database. A content management system is the trinity of these things."

Hence, on the one hand, the "content management system" further rationalized the creation of Encyclopedia content from a user perspective. On the other hand, its backend executed a number of rules that imbued the Encyclopedia's overall text body with additional coherence.

However, in spite of all these efforts to create a well-researched and coherent body of Encyclopedia entries, the "user retention" of this feature, that is, the time users spent scrolling through it, remained relatively low. As a consequence, starting around 2018, the FLORA team began working on a different feature which revolved around a different idea of text-based mobile extension.

3.2.3. Creating Plant Pro content

The second important feature that the FLORA team developed to provide users with text-based extension services is the so-called "Plant Pro." This subsection examines how the FLORA team created the content for the corresponding feature and the required infrastructure. As will be shown, given that this feature was linked with attempts to establish a business model based on the sale of aggregated user data, in working on it, the FLORA team has tried much more to adapt the advisory texts displayed by PHYTØ to the needs of users than in their work on the Encyclopedia.

The work on the Plant Pro began around the beginning of 2018 in reaction to the relatively low user retention of the Encyclopedia. The basic difference between the features can be summarized as follows: while the Encyclopedia feature mimicked a conventional reference work, the Plant Pro was intended to come closer to an actual extension agent, by providing users with "customized" content. In one of FLORA's onboarding documents, which was written when the Plant Pro was still in the planning stage, the idea of the new feature was summarized in a concise fashion. As FLORA described it at the time, the Plant Pro was to be a "planting calendar feature" that was to interact with users two to three times a week, giving them "all the needed advice to optimize the growth and productivity" of their crops. This explanation vividly captures the FLORA team's idea of providing a service that would, similar to an extension agent, accompany the user through the growing season. To achieve this, unlike the Encyclopedia content that was shown to users after a successful diagnosis or when they proactively searched for it in the app, Plant Pro content should be shown to users at regular intervals and remind them of reading it via push message.

As also alluded to in chapter one, the FLORA team did not develop this feature for purely educational reasons. Rather, the Plant Pro feature was an essential part of the startup's efforts to develop a business model that revolved around selling user data at the same time. As a reminder, the idea for this business model was that when users accessed the Plant Pro feature, they were asked questions about their farming operation (e.g., crops grown, area farmed, machinery used, type of farming, seeding date, etc.), in order to "customize" the Plant Pro content displayed to them. At the same time, FLORA planned to sell this data in aggregated form (e.g., district level, state level, country level) to interested third parties such as governments, food manufacturers, insurance companies, or pesticide manufacturers. Both for the educational and the economic side of the Plant Pro, it was important that users were interested in reading its content, which is why the FLORA team put a fair amount of work into creating it.

As with Encyclopedia content, the members of the plant team first defined what type of information should be included in the Plant Pro and then had a software developer design an interface with which they could write, edit, and deploy the respective texts on a daily basis. According to the onboarding document mentioned above, the basic idea for the content was that it "should contain all advice and best practice tips for all management needs of […] users." To achieve this, the FLORA team defined so-called "events" as the information unit of the Plant Pro content. In brief, these events are short texts on a wide range of tasks that may be performed throughout the cultivation cycle such as plant selection, weeding, irrigation, fertilization, plant protection, or harvesting, to name but some examples.

As mentioned earlier, these events should not only inform users about the described tasks, but also entice them to spend more time with the use of PHYTØ. More precisely, the aforementioned onboarding document envisioned that in a cultivation cycle of about three to four months the Plant Pro would provide users with 30 to 40 events per crop. At the time of writing the onboarding document, PHYTØ covered about 20 crops (compared to 30 today). For the production of Plant Pro content, this meant that the plant team was faced with the creation of 600 to 800 such events (compared to 900 to 1,200 today). Once this basic structure was defined, the plant team began translating content from agricultural and extension literature into Plant Pro content in a relatively linear fashion, similar to the way they had done it in the case of Encyclopedia content. In an internal team presentation held in November 2018 to the entire FLORA team, the plant team summarized their overall progress. By that time, the plant team had created 658 events with a total length of 180,000 words. In addition, they also presented their progress in terms of Encyclopedia content, where the team had now reached 674 entries totaling 300,000 words. To provide a frame of comparison for their colleagues, they added that the combined content of the Plant Pro and the Encyclopedia feature had the same word count as the entire "Lord of the Rings" trilogy.

Aside from these relatively large amounts of text, the most important novelty of the Plant Pro feature was that it was meant to display "customized" content to its users. As mentioned above, in order to do so, the FLORA team intended to tie the display of certain events to user-specific data.

Probably the most important data the plant team initially focused on in this process was the "growth stage" of their users' crops. The onboarding document explains the importance of this information as follows: "By telling us when they planted and how and what they plant, users receive information related to the current needs of their crop." In a similar vein, a member of the plant team underlined in an interview: "[T]he farmer uses the Plant Pro, and in the Plant Pro we have the sowing date, so we can estimate the stage of the plant without having the farmer involved." Nevertheless, the estimation of the growth stage via the planting or sowing date should only be an intermediate solution. In the long run, the onboarding document goes on to explain, the growth stage would be determined by means of image recognition algorithms, which should be developed for this purpose. As in the case of the construction of FLORA's algorithms for the recognition of crops and plant damages (see chapter 2), this meant that the startup planned to engage once again in the resource-consuming process of compiling comprehensive datasets containing images that displayed the crops covered by PHYTØ in all possible growth stages—a plan that has not been put into practice to date. In short, the growth stage was one first important information through which the FLORA team wanted to adapt the display of the educational texts of the Plant Pro feature to the individual situations of its users.

Another important type of information by which the FLORA team aimed to achieve this adaptation was the location of users. More specifically, as with the growth stage, the FLORA team planned to tie the display of Plant Pro content to the climate zone in which individual users were located. To do this, FLORA's software developers created an interface for the plant team that allowed them to generate so-called "Crop Cycles." As the onboarding document puts it, these Crop Cycles are "the default values" of the Plant Pro feature, that is, the main organizing unit that determines how and when a certain event is displayed to a certain user.

To create or modify such a Crop Cycle, the member of the plant team who uses the interface first needs to select a crop for which she would like to create or modify a Crop Cycle. In an example used in one of FLORA's onboarding presentations, a member of the plant team operating the interface chooses cotton. Subsequently, the interface invites her to select the climate zone for which she wishes to create or modify the respective cotton Crop Cycle. In the example at hand, the member of the plant team chooses a tropical rainforest climate. As a result, the interface proceeds by displaying the length of the total estimated cultivation cycle of cotton in a tropical rainforest climate (224 days), and the estimated lengths of the seven individual growth stages that cotton plants are expected to go through in that particular climate zone. More importantly, in addition to a numerical representation, the interface also displays these periods on an Excel spreadsheet-like timeline, that is, a timeline with an X-axis and a Y-axis on which different events can be arranged (where the necessity of the Y-axis lies in the fact that the events may overlap). The member of the plant team then continues by dragging and dropping the plant team's pre-written events from the so-called "event bucket" into the timeline, thus filling or modifying the Crop Cycle of cotton in a tropical rainforest climate with instructions for agricultural practices that—in an ideal scenario—should be displayed to farmers at an opportune time.

Another important information by means of which the FLORA team intended to "customize" the content of the Plant Pro feature was the "cultivation type," that is, whether users were practicing "organic farming" or "conventional farming" and what their level of "mechanization" was. For this purpose, all events should be annotated according to the cultivation type to which they applied, so that, to stay with the example, there would be no confusion between the Crop Cycles displayed to conventional cotton farmers and those displayed to organic cotton farmers or more mechanized cotton farmers and less mechanized cotton farmers. In other words, FLORA planned to create different versions of each Crop Cycle, that is, Crop Cycles for the same climate zones, which were equipped with different events, depending on the cultivation types of users.

In short, all of these efforts were aimed at ensuring that the content of the Plant Pro feature would increase PHYTØ's "user retention." On the one hand, this increase in user retention was to augment the effect of PHYTØ's mobile extension services on farmers' actions, on the other hand, it was to help create a working business model for the app. To achieve this goal, the FLORA team put a lot of work into the "customization" of Plant Pro, that is, in linking the display of this content with selected user data (e.g., growth stage, location, cultivation type). As soon as an initial working version of the Plant Pro feature was completed, the FLORA team began testing it in India.

3.2.4. Testing Plant Pro content

In late 2018 the plant team together with members of the "Android team," FLORA's specialists in terms of "user experience research" (see chapter four), travelled to India to "test" the content of the Plant Pro events in face-to-face interactions with users. As this subsection will show, these exposures of users to the advisory texts of the Plant Pro did not go as the FLORA team had envisioned in that users seemed uninterested in the texts or were even repelled by them.

In contacting the farmers that were to take part in the testings, the delegation of the German FLORA office was assisted by the staff of the two Indian regional offices. Once contact was established, the primary method of "content testing" consisted of exposing the selected farmers to parts of the texts and illustrations included in the Plant Pro feature and asking them for their opinions. As the FLORA employees in charge of the testing noted in a PowerPoint presentation they held upon their return to Germany, they usually asked users: "What do you think about this information?"

Similar to the Encyclopedia content before, the results of this test were not positive. As the employees in charge of the testing continued to explain, during their trip they had identified four primary flaws with regard to the content of the Plant Pro events which they summarized on a PowerPoint slide for their colleagues upon their return. First, the slide notes, "Some content is still too technical" explaining that "Some vocabulary [is] unknown.'" Second, the slide states "Too much information vs. some information is missing," specifying that farmers are not interested in names of "active ingredients," but in "brand names." Third, the slide points out that “some events are not interesting.” As examples of such uninteresting events, the slide mentions that “farmers [who are] selling product directly to factories [are] not interested in post-harvest processing” or that “storage advice for vegetables” was often not needed because “most farmers do not have cooling facilities.” Finally, the slide highlights that the “readability” of the events was good although they “may appear too long” to users.

This dissatisfaction with the Plant Pro content was also reflected in interviews I conducted with members of the FLORA team. To give an example, in the following quote, a member of the plant team who took part in the India trip summarizes the results of the content testing and the consequences they derived from it:

> “We found out quickly that the Plant Pro that was originally developed to improve retention, so, to be more like a daily buddy to a lot of tasks and activities- So, there was a lot of content that was thinned out […]. And it became clear that we were losing the user in a sense, because it was a bit of information here, a bit of information there, etc. So, following the trip and starting the new year, we were like: ‘Okay we need to rework the Plant Pro, make it less complicated and straight to the point, what they are interested in.’ So, that was kind of my main task in the beginning of the year, kind of condensing everything back together, keeping the bare minimum, or the most valuable information.”

As illustrated by this quote, the FLORA team evaluated the Plant Pro feature not only via content testing in the field, but also, as with Encyclopedia content, by measuring its user retention. As the quote makes clear, contrary to all expectations, the Plant Pro feature initially even led to a loss of users’ interest in the app. This realization, coupled with the insights generated through the content testing in India, ultimately led the plant team to conclude that the content of the Plant Pro feature, which they had created so carefully in the preceding months, should be reduced to “the bare minimum.”

As the head of the plant team portrayed it, another important insight they took away from their work on the Plant Pro feature was that Indian farmers were less interested in non-chemical measures to address plant damages than his team had anticipated or hoped for. To emphasize this point, he explained how his team had initially tried to give greater importance to non-chemical events when designing the Plant Pro feature by displaying them before events that involved chemicals, but then realized that displaying non-chemical measures before chemical measures caused their users to close the app:

> “In the Plant Pro we always had that as the first premise, so to speak, that we push such things forward, that we don’t use herbicides, but they have to do it by hand. Then we tested it and then

> people opened it up and said: Phew, hand weeding no one does that anymore around here. I simply use herbicides. I don't need it [the app]. Closed."

As this quote captures, FLORA's experience with the Plant Pro can be seen as a trigger that led the team of the startup to fundamentally rethink its conception of the mobile advice provided by the PHYTØ app. In other words, the experience with the Plant Pro and its sparse use led the FLORA team to view PHYTØ's role less in the provision of advisory texts prescribing users non-chemical crop protection measures and more in assisting them in their use of chemical pesticides. In an interview, one of the co-founders of FLORA illustrated this transformative experience quite vividly:

> "Okay, we can use this power that we have to a certain extent by preparing and presenting knowledge and making it available to these users. A little bit of change processes but they are super slow. We don't need to kid ourselves about that. So, all this content that we produce, we can see how much of it is read. Most of them say: 'Diagnosis, now I spray! What should I pour on it? Give medicine!'"

As this quote sums it up neatly, despite the increased "customization" of content, PHYTØ users had still little interest in the advisory texts of the app. Rather, the FLORA team made the experience that following a diagnosis, most PHYTØ users immediately requested information on suitable pesticides to treat the identified plant problems. This experience and their experience with the Encyclopedia prompted the FLORA team to transition to what I call the "late phase" of FLORA's mobile extension services.

3.3. Late phase: Enacting expertise through pesticide recommendations

In the late phase of PHYTØ's mobile extension services the app's enactment of expertise proceeds through the display of brief recommendations of chemical pesticides, biological pesticides, and other non-chemical crop protection measures. Accordingly, this second section of the chapter examines the work through which the FLORA team generates these pesticide recommendations in the back office of the startup. As the previous section, this section revolves around the work of FLORA's plant team and several other members of the FLORA team who support their work. As will be demonstrated, the creation of pesticide recommendations is rooted in more specific assumptions about a pesticide-related knowledge deficit on the part of Indian farmers and unfolds through the practices of ranking pesticides, selecting pesticides, and explaining their "proper use."

3.3.1. The problem of a pesticide-related knowledge deficit

The plant team's work on PHYTØ's pesticide recommendations is accompanied by strong assumptions about a pesticide-related knowledge deficit among Indian farmers. These assumptions can be seen as a specification of the previously described assumptions of a general knowledge deficit on the part of small-scale farmers in Global South countries that has solidified within FLORA over time. Hence, in the case of this subsection too, a clear parallel emerges between the work of the startup and Jas' (2005) description of "the construction of a double image of the peasant" (p. 50) in historical France. As will become clear, this parallel consists in the fact that FLORA too discursively constructs the image of a large mass of ignorant farmers, who might be transformed into knowledgeable farmers through the use of the right technology, PHYTØ.

A characteristic illustration of how members of the FLORA team describe the perceived lack of knowledge of Indian farmers with respect to pesticides is provided in the following quote, in which one of the co-founders of the startup recalls an experience he had on one of his professional trips to India, where he witnessed what he thought was a highly problematic use of a particular pesticide called Chlorpyrifos:

> "These are simply people who have little clue [...]. Where almost something like a culture develops: If you have something like sucking insects, it is always good to mix in a little bit of Chlorpyrifos. And you can say as much as you want that this and that product is somehow cooler and not quite as toxic, they always mix in a little Chlorpyrifos, because that's just tradition, so to speak."

The co-founder highlights the misuse of chemical pesticides by Indian farmers by describing how Chlorpyrifos is applied even in cases where it might not have any effect. Moreover, the co-founder describes the reasons for this misuse of chemical pesticides as rooted in the "culture" or "tradition" of Indian farmers, which makes it, in his representation, particularly difficult to change it at all. A similar picture was painted in an interview with a member of FLORA's plant team. As will become clearer, the quote contains a somewhat different characterization of the misconduct of Indian farmers in the use of pesticides. More importantly, however, it gives an indication of what consequences the interviewee and the rest of his team draw for their actions from the confrontation with this questionable use of pesticides:

> "I know exactly what it looks like in India right now, what blatant pesticide pollution they have there. So, when I went to India lately, it was a horror for me to buy spices because I know how much is on them. I know that people are like: Yes, okay, I don't spray for myself, but for the

> things I sell, I spray today and sell tomorrow. I don't give a shit. That's just the way it is. And to change these things is much more important to me than to say: Hey, we have to make everything organic now."

Similar to the previous interviewee, the member of the plant team begins his account with an anecdote from a trip to India, where he witnessed with his own eyes how Indian farmers misuse pesticides. However, the interviewee does not claim that Indian farmers are ignorant about the risks of pesticides, as the previous interviewee did. Rather, he claims that farmers know about the risks but do not care about them unless they affect them personally. In other words, he accuses Indian farmers of a general lack of responsibility in the use of pesticides.

What is important at this point is the implication that the plant team draws from this assessment. More specifically, as the interviewee points out, the plant team has drawn the implication to prioritize actions to correct such perceived misbehavior among Indian farmers over trying to persuade these farmers to fully convert to organic farming. This derived implication should be understood in light of the fact that FLORA, in the early phase of PHYTØ's mobile extension services, particularly in the work on the Plant Pro feature, placed a much greater emphasis on encouraging farmers to adopt non-chemical crop protection measures. In other words, the implication that the head of the plant team describes can be interpreted as a reaction to the experiences that he and the rest of his team made with the Library and Plant Pro features. This becomes even clearer in the next quote from the same member of the plant team, in which he describes why displaying non-chemical crop protection measures too dominantly within the user interface of PHYTØ could even be counterproductive to addressing the perceived knowledge deficit of Indian farmers:

> "So, if you were to propose all these measures to a farmer, how he should now get along without pesticides, or only get along on organic pesticides, that would mean so much change for him that he would never go along with us in the app. So, we would already lose him by saying that you now have to do hand weeding, right?

This quote is crucial in understanding PHYTØ's approach to social change. As this quote indicates, in the perception of the FLORA team, reducing the use of chemical pesticides or supporting a more responsible use of these substances through the app seems to be an achievable goal, while completely eliminating them from their users' fields does not seem to be one. In other words, although the plant team is well aware that more drastic changes in pesticide use by Indian farmers would be desirable, it chose to generally promote less drastic changes in the hope of effecting any change at all. At this point, an insightful similarity emerges between the work of the plant team and the work of the extension agents studied by Henke (2008). If we think back, Henke described in-person extension as a "fundamentally conservative technique of social change" (p. 146), because of the constant concern of extension agents that their advice might be rejected by farmers, and because of the agents' reaction of toning down their suggestions for behavioral change. In short, the same pattern emerges in the aforementioned accounts of the head of the plant team, though so far there is much to suggest that mobile extension seems to be an even more conservative technique of social change than in-person extension, since the enactment of agricultural expertise via an app seems even more fragile than the enactment of agricultural expertise in the field.

3.3.2. Ranking pesticides

A first important practice in creating PHYTØ's pesticide recommendations is to rank how recommendations for chemical, biological, and other non-chemical crop protection measures are being displayed in the app's user interface relative to one another.

As summarized again in the next quote from one of the co-founders, the reason they chose to recommend chemical pesticides, despite their early preference for more alternative approaches to crop protection, was that they were concerned about repelling users by not doing so:

> "That was actually a strong argument at the time: We're losing the opportunity to pull people who swear by chemical treatment, or who do it because that's the way they have always done it, onto 'the right side,' in quotation marks."

In other words, since the members of the FLORA team did not believe they could fully convince farmers to use biological pesticides or other non-chemical crop protection measures via their app, they hoped to pique farmers' interest by providing content on chemical pesticides and subsequently draw them to the "right side," by which the interviewee refers to the use of biological pesticides and other non-chemical crop protection measures. To do this, the FLORA team implemented what could be referred to as nudging mechanisms in the PHYTØ user interface. The head of the plant team described this approach as follows:

> "We said: Hey, we always try to present the biological ones a little more prominently, that is, to put them in the first place, for example, and still show the whole range of treatment options, from preventive to biological to chemical, so as not to exclude anyone."

Put differently, FLORA tried to gently lure farmers into using biopesticides by giving these products a higher priority in the information architecture of PHYTØ. The same applies to other non-chemical crop protection and preventive measures, which are always displayed before chemical pesticides in the user interface of PHYTØ. A similar practice is described by one of the co-founders in the next quote, in which he describes another approach the startup takes to subtly influence farmer behavior through a specific way of displaying pesticide recommendations:

> "Okay, we do intervene to a certain extent, for example by ranking things differently, promoting them differently, presenting them differently, also in the sense that we don't endorse any products, or any product advertising, or any brand names in that sense. For example, we don't say: 'By the way, the Bayer product works better than the Syngenta product,' but we just say that such and such and such active ingredients have proven to be effective."

Besides the already mentioned prioritizing of biological pesticides and other non-chemical crop protection measures in the information architecture of PHYTØ, the quote describes another practice by which the FLORA team sought to avoid a too unrestricted endorsement of chemical pesticides in the app. In order not to advertise, the FLORA team originally did not display names of products and companies in the app, but only active ingredients. Nevertheless—as also shortly reflected in the subsection on testing Plant Pro content—the FLORA team found that PHYTØ users had little interest in names of active ingredients, so the practice of not displaying product and brand names was abandoned relatively quickly. Instead, as described in the subsequent quote by one of the co-founders, the FLORA team transitioned to a different practice to ensure that PHYTØ did not recommend pesticides unrestrictedly:

> "And now we have just decided: Okay, if we know these ingredients work, then we simply list all manufacturers where we also presume that they offer a certain quality. So, there are also many smaller manufacturers who adulterate their products, which is also the reason why in India people always apply double or triple the amount, because it [the product packaging] says 12 percent, but there's only 3 percent in it, and that's why we recommend [the products from large manufacturers], which of course doesn't support the small brands. But then they have only themselves to blame."

Hence, responding to users' interest in brand names the FLORA team eventually went about displaying a list of manufacturers for each active ingredient whose products they were confident met certain quality standards, which mostly amounted to large manufacturers.

Taken together, these descriptions of the practices through which the plant team attempts to intervene in the pesticide use of PHYTØ users show that the enactment of expertise through pesticide recommendations of a mobile app is anything but a top-down process. Rather, it is a collective achievement unfolding between the developers of the app, the users of the app, and the app itself, who jointly determine, in an ongoing back-and-forth, what counts as expert advice with respect to pesticides and what does not. Yet, unlike in-person extension agents FLORA cannot immediately communicate with farmers. For this reason, the startup has developed a number of alternative communication mechanisms, namely, as shown in this subsection, ranking, arrangement, and (non-)disclosure of information about pesticides. In other words, FLORA has developed a number of additional devices that take part in PHYTØ's collective enactment of expertise.

3.3.3. Selecting pesticides

Besides deciding how to display pesticides in the PHYTØ user interface, another important task for the plant team in developing pesticide recommendations is the actual selection of pesticides or respectively active ingredients that should be listed by the app. Here, the plant team has somewhat different approaches as far as biopesticides and chemical pesticides are concerned.

As for the selection of biopesticides and other non-chemical crop protection measures, one of the main tasks for the FLORA team is to check whether they can find scientific evidence of their effectiveness. As described in an informational video about PHYTØ produced by the ICRISAT featuring the head of the local FLORA office, the start-up has a wide variety of non-chemical alternatives to chemical pesticides to choose from, ranging from "traditional practices" to modern "biopesticides." In light of this, the head of the local office explains, FLORA bases its selection of these non-chemical crop protection measures solely on the availability of scientific evidence about their effectiveness:

> "One of the questions that arises during our interactions with farmers in the field has always been whether we should go for chemical control or biological control, or other systems like natural farming practices, some traditional, and local practices that were passed on from other farmers, or their forefathers, and there is a repository of a lot of wisdom out there, in farming. We don't want to lose all that. Right now, whenever there is evidence in research, that scientific information is placed in the app […], like for example: biological control is already existing, and there is scientifically proven information available for many crops, so that finds place right in the beginning and upfront, then comes information on chemical control […]."

In practical terms, the plant team applies various loosely formalized methods to assess the effectiveness of the non-chemical measures that ought to be recommended by PHYTØ. On the one hand, they conduct research via the internet, scientific databases, and scientific literature.

On the other hand, for more detailed questions, they draw on a network of specialists with relevant experiences which the FLORA team has established over the years (e.g., researchers, extension agents). In the user interface of PHYTØ, the results of this research are displayed as a list of possible non-chemical treatments and products, leaving the final selection to the user (see Figure 4):

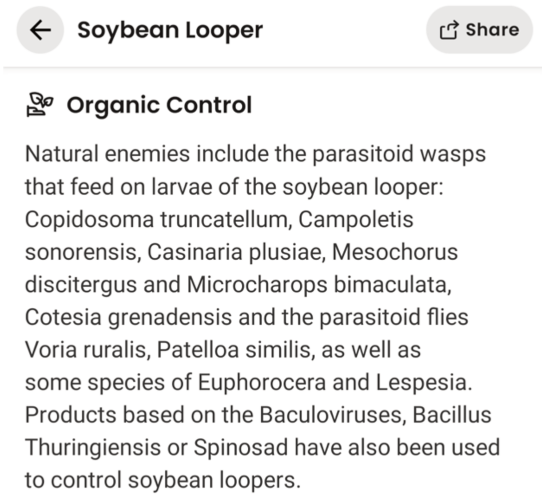

Figure 4: "Organic Control" (Source: Screenshot of PHYTØ's user interface)

Considering the sheer quantity of chemical pesticides available on the market and the severity of the problems these substances can cause if used incorrectly, a much larger portion of the plant team's work goes into selecting which of these chemical pesticides ought to be recommended by PHYTØ. In an interview, a member of the plant team summed up this problem as follows:

> "We will always have more than one product to recommend, in the sense that it is legally registered in India, that it is recommended by the government or the board of pesticides or researching universities to be effective against certain pests on certain crops. So, our next question was: How do we know which one to push forward?"

In contrast to the selection of biopesticides and other non-chemical crop protection measures, the selection of chemical pesticides is less about searching for evidence of their effectiveness, and more about narrowing down available options. On a practical level, the FLORA team usually approaches this problem by gathering documents issued by the different Indian state agencies that detail the pesticides that are approved in a given state. In addition, these documents usually contain recommendations regarding the dosages for these approved pesticides. As a member of the plant team put it: "The good thing about pesticides is that they are super heavily regulated. There are actually quite a few good PDFs." In a next step, the plant team feeds this data into a database in a relatively unmodified form. One of them summarized this procedure as follows:

> "[W]e simply entered it here with our team, blindly, just like that: 'This is the recommendation from the government. This can be done, and this is the dosage for it.' We simply adopted that. That's how we often do it, so that we actually build up a foundation relatively quickly."

Hence, comparable to the creation of the first Encyclopedia content, the work on PHYTØ's pesticide recommendations began by gathering pre-existing information in the startup's database. Again, comparable to the creation of FLORA's text-based extension services, this step was followed by a process of reviewing the translated pesticide recommendations. As one of the co-founders explained it in an interview, one of the practices they used for this purpose was to subject the pesticides admitted by the Indian government to stricter safety standards maintained by international institutions:

> "[W]e also said: 'Okay, we are stricter than the Indian legislation and throw out everything that is banned by the World Health Organization, WHO, and the EU as extremely harmful.' We simply don't recommend it, so maybe you can buy it in the store, but we say: 'Don't buy it because it is crap.'"

In practice, this meant that the plant team created a database listing four different toxicity classifiers (Ld50, GHS, WHO, Indian Government) for each active ingredient under consideration, before using this comparative device to narrow down their list of potential recommendations. In addition, as with biopesticides, the plant team relied on online research, scientific databases, as well as databases for extension scientists such as that of the CSREES, to come up with tentative lists of active ingredients they deemed adequate for the treatment of the plant damages covered by PHYTØ. Whenever the plant team completed such a list, it was forwarded to local specialists in India (e.g., ICRISAT affiliated researchers, professors from agricultural universities, extension agents) for final corrections. In the user interface of the app, this approach often results in the display of multiple active ingredients and a selection of the respective products and manufacturers for a given plant damage, with the less toxic substances higher up and the more toxic substances lower down, leaving the final choice to the user (see Figure 5).

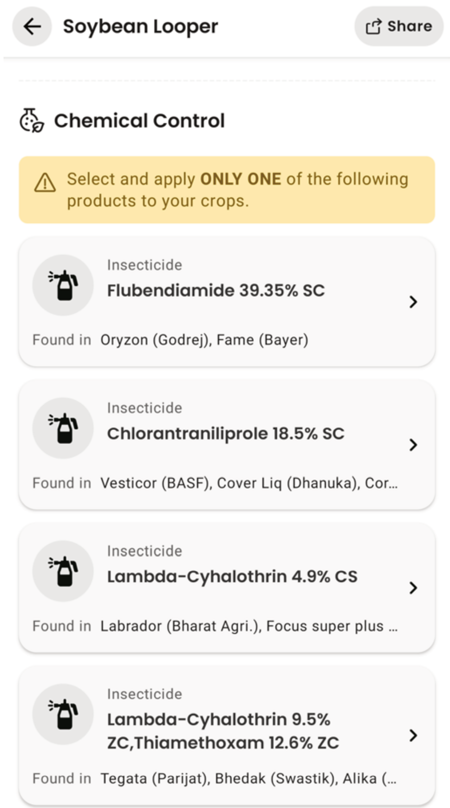

Figure 5: "Chemical Control" (Source: Screenshot of PHYTØ's user interface)

The practices described in this subsection refine the picture of how PHYTØ's pesticide recommendations enact agricultural expertise. More specifically, they make clear that the plant team sees its task primarily in reviewing and selecting biopesticides, other non-chemical crop protection measures, and chemical pesticides, and feeding these selections into the app. The actual enactment of expertise via PHYTØ then proceeds by displaying this list to users without (except in cases where only one active ingredient is eligible) giving a definite recommendation.

3.3.4. Explaining the proper use

A final important step through which the plant team prepares the pesticide recommendations of PHYTØ consists of providing users with explanations for "the proper use" of these substances.

As one member of the plant team summed it up in an interview, "if you use it [pesticides] in a proper way, it's going to be good." What exactly is meant by this "proper" use becomes clear in the next quote from the same plant team member:

> "The situation in many areas is so bad, so bad, like there is no space for us to do something wrong. Because in the end of the day we tell them: wear your clothes, put your shoes, wear gloves, put the mask, and spray the thing."

This quote reflects a widely held belief within FLORA, namely that Indian farmers are so irresponsible or ignorant in their use of chemical pesticides that even minor education about how these substances work, along with occupational health and safety measures, would greatly improve farmers' health and the environmental damage caused by their practices. As a consequence of this belief, FLORA has decided that all pesticide recommendations issued by PHYTØ ought to be accompanied by instructions for proper use (Figure 6) and lists of recommended occupational health and safety measures (Figure 7).

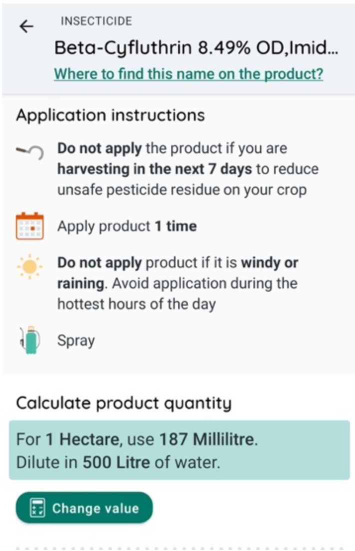

Figure 6: "Application instructions" (Source: Screenshot of PHYTØ's user interface)

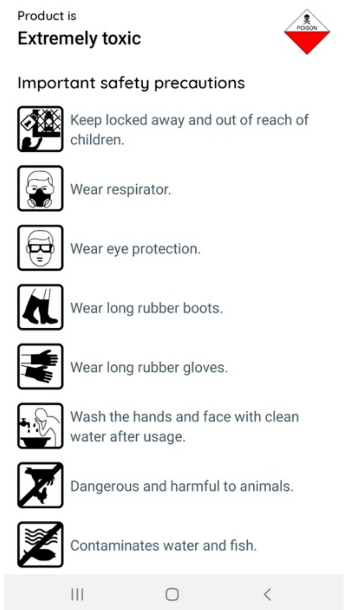

Figure 7: "Important safety precautions" (Source: Screenshot of PHYTØ's user interface)

As in the case of the selection of products, and in the absence of control mechanisms that could be carried out at a distance, PHYTØ leaves the decision of whether to follow these instructions to its users. In addition to these instructions, over the years, the plant team has also thought through other, more interactive approaches to make the pesticide use of PHYTØ users less harmful to people and the environment. In particular, they envisioned incorporating procedures inspired by "integrated pest management" (IPM) into PHYTØ's pesticide recommendations.

To provide some background, since the emergence of IPM in the late 1960s, numerous interpretations of the term have emerged. To give an example, the EU framework directive on the sustainable use of pesticides has provided a widely used definition:

> "'Integrated pest management' means careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment. 'Integrated pest management' emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms." (Directive/2009/128/EC)

Agronomists typically translate definitions like the one above into a varying number of principles (Barzman et al., 2015). These principles often provide a step-by-step plan to help IPM practitioners decide at what level of infestation what intervention is deemed appropriate. For example, IPM practitioners—akin to PHYTØ—usually recommend using non-chemical crop protection measures in the case of a light infestation and resorting to chemical pesticides only in the case of a more severe infestation.

During a stay at FLORA's German office, I had the opportunity to attend a presentation in which one of the members of the plant team shared with the rest of the FLORA team how this IPM-inspired approach should be incorporated into PHYTØ's pesticide recommendations. To this end, the member of the plant team presented two decision trees depicting an "ideal IPM route" and a "safe IPM route".

As explained on the slide, the "ideal IPM route" begins with the "Crop Scan," that is, with a diagnosis via PHYTØ's automated image recognition. In the fictional example used by the member of the plant team for the purposes of the presentation, the Crop Scan determines that the problem consists of white flies in tomatoes. Subsequently, the fictional PHYTØ app recommends monitoring the severity of the infestation with sticky traps assuming a threshold of four adult flies per sticky trap. If the infestation is above this threshold, the fictional PHYTØ app would consider it a “heavy infestation” and recommend chemical pesticides. If the infestation is below this threshold, it would assume a “light infestation” and recommend biological pesticides. Accompanying that, the decision tree envisages non-chemical cultural practices. However, at the time of the presentation, it was not yet entirely clear whether or how PHYTØ would be able to make users use sticky traps or any other monitoring technique at a distance, as this would require a considerably higher level of interaction than using the Crop Scan. In other words, the plant team assumed that it would be more difficult to get users to correctly use more sophisticated monitoring techniques such as sticky traps via PHYTØ than it would be to get users to correctly use the Crop Scan.

For this reason, the plant team has worked out the “safe” route. The difference between the “safe” route and the “ideal” route was that the “safe” route did not envisage any monitoring at all. Again, the fictional Crop Scan in the example mobilized for the purposes of the presentation detected a problem with white flies in tomato. Subsequently, the fictional PHYTØ app would decide whether a user should apply a biological or a chemical pesticide based on a number called the “pre-harvest interval” (PHI). The PHI is a number found on pesticide labels that indicates the minimum amount of time that should lie between the last application of a pesticide and the harvest date of the crop on which the pesticide was applied. Since PHYTØ asks users for the sowing dates of their crops, the app can roughly calculate when users will harvest them. Thus, the member of the plant team went on to explain, should the PHI between the detection of the white fly problem and the anticipated harvest date be long enough, the app would recommend a chemical pesticide. In turn, should the PHI be too short, the app would recommend a biological pesticide. To put it in conceptual terms, the “safe” route reduced the complexity of the collective involved in PHYTØ’s enactment of IPM-related expertise, and thus its susceptibility to error.

Once again, the practices described in this subsection demonstrate the collective nature of PHYTØ’s enactment of expertise and how the developers add or remove different elements to this collective, that is, how they test different degrees of collectivity as a function of measured or anticipated user capacities, leading them to balance what they believe to be “ideal” advice with advice they believe users can realistically be expected to follow.

Conclusion

This chapter has shown how providing agricultural expert advice via a smartphone app is a constant balancing act between what developers and users of such services consider to be adequate extension. Building on debates in the "anthropology of expertise" (Carr, 2010), the chapter has argued that the agricultural expertise that an increasing number of extension apps are said to hold (i.e., PHYTØ the "digital expert in your pocket") should be seen as a collective enactment that is maintained from the back offices of the respective providers. In the case of FLORA, and PHYTØ respectively, this maintenance proceeded through a gradual transformation of the form of the app's extension services and their underlying idea of expert advice. More precisely, the chapter has identified two successive phases in the mobile extension services provided by PHYTØ. First, an early phase in which the plant team focused its efforts on providing users with lengthier text-based advice, while giving relatively narrow instructions of how they should farm. Second, a late phase in which they focused more on giving users a selection of concise pesticide recommendations without explicitly saying which of the suggested crop protection measures they thought was best. The chapter suggests to conceive of this gradual shift as a balancing act because it was driven both by impulses set by the providers (e.g., design of new feature) and impulses set by the users of PHYTØ (e.g., sparse use of a new feature). At this point, one aspect needs to be clarified. Although the chapter draws a clear, analytical line between the early and late phase of PHYTØ's mobile extension services, the design elements and contents that emerged from these two phases are intermingled in PHYTØ's present-day user interface. To give an example, many of the advisory texts written during the early phase of PHYTØ's mobile extension services can still be found in the app today, in recycled form, so to speak. What has changed, however, is the amount of attention that the FLORA team pays to the two different forms of mobile extension services (1. advisory texts, 2. pesticide recommendations) in the back office of the startup. What implications can be drawn from these findings for the debates about in-person extension and mobile extension with which this chapter began?

To start with the debates on in-person extension, as the chapter has noted on multiple occasions, there are clear parallels between the discourse that, according to Jas (2005), led to the rise of agricultural science in France and the discourse that accompanies the foray of FLORA into India. This was most evident, in the way the providers of the mobile extension service PHYTØ talk about Indian farmers. In line with Jas' observation of "the construction of a double image of the peasant" (p. 50) in historical France, the chapter has shown how the efforts of the developers of PHYTØ are based on two images of Indian farmers. On the hand, they are based on an image of Indian farmers as a large, homogenous ignorant mass, especially with regard to pesticides. On the other hand, they are based on the image of farmers who are or could be freed from this ignorance through the use of PHYTØ. In short, just as the discursive construction of a double image of farmers served the agricultural scientists in Jas' study as a pillar for the dissemination of agrochemicals and a more general principle of an intensive, capitalist agriculture, it serves the providers of mobile extension services, like PHYTØ, to propagate their technologies and ideas.

Turning our attention to Scott, we are confronted with a less smooth juxtaposition. More specifically, it seems that the enactment of expertise by the extension agents described by Scott (1998) and the enactment of expertise by PHYTØ could not be more different, at least at first glance. While the extension agents in Scott's study operate on behalf of the state, PHYTØ is operated by a private company. While Scott situates the efforts of the extension agents in a series of large-scale modernization projects (e.g., dam building, urban reform, villagization), PHYTØ seems to be more akin to the rise of little development devices (Collier et al., 2017). While the extension agents that Scott describes remodel entire agroecosystems in the name of science, and in an authoritarian manner, PHYTØ counts on small modifications in the behavior of farmers. However, a common denominator between the extension agents described by Scott and the case of PHYTØ can be seen in what he refers to as acts of establishing "legibility." As he specifies it legibility denotes a condition in which states hold vital information about societies and environments that they intend to govern. However, which complicates things, the knowledge that matters to central authorities is not necessarily the knowledge that matters in the situated practices of local populations. As a consequence, this local knowledge must be put into an administratively graspable format and thus made "legible" for central government agencies, which usually involved material interventions in the societies and environments that were to be governed. It is in this difficult-to-avoid neglect of local knowledge in the process of creating more universal knowledge of rural societies and environments (also documented in chapter 2 and chapter 4 of this thesis), where the common ground between the extension agents described by Scott and the providers of a mobile extension service described in this chapter lies. In more concrete terms, the case of PHYTØ should be read as an example of how attempts are being made today to make crops, plant damages, and small-scale farmers legible and thus susceptible to control by powerful outsiders (e.g., investors, companies, states). The fact that FLORA is not a state but a startup does not detract from this argument. On the contrary, the chapter should be read as an account of how the practices of establishing legibility that Scott observed have morphed over the years. However, it must be remarked that there is, of course, no guarantee that this quest for establishing legibility, which is observable in many mobile extension services, will always succeed.

Moreover, the findings of this chapter contribute to the debates initiated by Cash (2001) and Henke (2008), who portray agricultural extension agents as a group of individuals who seek to establish cooperation between science and farmers in a relationship that strives for reciprocity, while exploring the question of how this cooperation is established in practice. For this, Cash looked at a very well-established extension organization, the CSREES, and a widely-accepted agriculture-related water conservation project. Henke, on the other hand, and more resonant with the case studied in this chapter, examined a group of less-established agricultural extension agents who aimed to persuade farmers to adopt more environmentally friendly agricultural practices, while continuously fearing that the farmers would break off contact with them. One argument Henke developed in the course of this study is that in-person extension constitutes a "fundamentally conservative technique of social change" (p. 146) since extension agents constantly fear that farmers will deny them access to their fields if the changes that they propose deviate too much from farmers' usual practices. Building on this argument, the findings of this chapter suggest that mobile extension services like PHYTØ may well constitute even more conservative techniques of social change, since the digital user interface is in most cases the only link between the providers of such services and farmers, and, as the results of this chapter further indicate, not a very strong one at that. Simply put, the scenario of farmers ceasing to use a mobile extension app, thus denying providers access to their farm life, is very real. The "conservative" response to this seems to be that providers of such services, as FLORA did, align their expert advice very closely with farmers' usual practices, while refraining from suggesting more profound behavioral changes.

In a similar vein, the chapter illustrates some of the difficulties of establishing what Le Velly and Goulet (2015) call "commercial attachments" via the interface of a mobile extension app, thus adding a layer to their analysis of private agricultural extension. Even if commercial issues are only peripherally addressed in the chapter, the process it covers must be understood as what Le Velly and Goulet refer to as a process of "[s]ingularization of the relationship with the product through advice" (p. 12), that is, one of the five mechanisms through which the extension agents studied by Le Velly and Goulet establish commercial attachments. In more general terms, when comparing PHYTØ and the commercial extension agents discussed by Le Velly and Goulet (2015) it is noticeable that the influence that the former has on the behavior of farmers is weaker—a point closely related to the previous point of FLORA being a conservative technique of social change. From the ANT-informed perspective that undergirds Le Velly and Goulet's argument this can be explained as follows: Extension agents who operate in the field can enlarge the collective needed for a successful enactment of expertise through practices that directly involve the materiality of the farm (e.g., by making farmers look at a soil profile, count the number of weeds in a square meter of pasture, or taste a leaf of freshly grown lettuce). In more conceptual terms, they can enrol additional actors as needed to substantiate their enactment of expertise. In the case of mobile extension, on the other hand, it may be possible to refer to these additional actors with words and images, or implement nudging mechanisms,but it cannot be ensured that a direct material attachment, or detachment (cf., Goulet & Vinck, 2012), will occur, as communication between providers and farmers is in the vast majority of cases limited to the two-dimensional user interface of the corresponding apps. This raises the question of why such technologies are nonetheless so appealing to private providers of mobile extension services.

This question segues into the debates on mobile agricultural extension outlined at the beginning of this chapter. As has been shown, agricultural economists and development economists in particular have high expectations about mobile agricultural extension and often present it as a way to overcome efficiency, qualification, and accountability problems, to name a few, in the field of in-person extension (e.g., Ferroni & Zhou, 2012). At the same time, some of these scholars presented concerns of how "market failures" (Fabregas et al., 2019) might erode the potential of mobile extension services. In response to this economic perspective, the chapter devised an alternative anthropology-inspired (Stone, 2011) explanatory model for the success or failure of mobile extension services, assuming that this success or failure depends primarily on the "enactment of expertise" (Carr, 2010) of a given project. Through this approach it was shown that "successful" mobile extension does not necessarily depend on the "truthfulness" of the knowledge communicated or the "efficiency" of this process, as many economists argue, but most importantly on how well the providers of mobile extension services are able to anticipate or test the advisory needs of users at a distance and adapt their enactment of expertise accordingly.

4. Representing small-scale farmers as users

Summary of the chapter in French (for formal reasons): 4. Représenter les petits agriculteurs en tant qu'utilisateurs

Le quatrième chapitre traite de la question de savoir comment FLORA génère des connaissances sur les utilisateurs de PHYTØ. En termes théoriques, le chapitre conceptualise cette production de connaissances comme un processus de génération continue de "représentations de l'utilisateur" (Akrich, 1995) au moyen de différentes "techniques de représentation de l'utilisateur" (ibid.). En suivant Akrich, le chapitre part du principe que le problème des développeurs de technologies telles que PHYTØ n'est pas de créer des représentations d'utilisateurs, mais d'aligner les représentations d'utilisateurs divergentes qui apparaissent au cours de ce processus pour créer une représentation globale cohérente qui peut informer le développement de la technologie en évolution. Empiriquement, le chapitre montre que deux types de techniques de représentation des utilisateurs sont utilisés au sein de FLORA, celles qui fonctionnent à distance (par exemple, les mesures de performance numériques) et celles qui fonctionnent sur le terrain (par exemple, les tests de prototypes), pour générer continuellement de nouvelles représentations des utilisateurs de PHYTØ, c'est-à-dire pour produire des connaissances sur les utilisateurs de PHYTØ. Sur cette base, le chapitre continue à démontrer qu'au sein de FLORA, une représentation dominante de l'utilisateur prévaut, qui dépeint les utilisateurs de PHYTØ et MERCHANT comme un groupe croissant d'agriculteurs et de vendeurs de pesticides qui reconnaissent les avantages pratiques des applications et qui les utilisent en conformité avec cela—une représentation de l'utilisateur qui est fortement influencée par les attentes des capital-risqueurs à l'égard de la startup. En outre, il est également démontré que les représentations des utilisateurs générées à distance, en particulier, sont d'une grande importance pour les investisseurs, car elles permettent d'évaluer de plus grands groupes d'utilisateurs, alors que les représentations des utilisateurs générées sur le terrain se réfèrent généralement à des utilisateurs individuels ou à de petits groupes d'utilisateurs. Toujours en suivant Akrich, le chapitre identifie ensuite certaines des « stratégies » que l'équipe FLORA a développées pour aligner les représentations des utilisateurs déviants avec la représentation dominante des utilisateurs de la startup. Ces stratégies comprennent l'ajustement des mesures de performance, l'embauche d'utilisateurs experts ou la collectivisation des expériences faites avec les utilisateurs déviants sur le terrain. Ces stratégies doivent être considérées comme un mécanisme vital pour soutenir le travail sur PHYTØ. Le chapitre conclut que les interactions de FLORA avec les utilisateurs suggèrent qu'avec l'expansion de l'agriculture numérique, le

caractère semi-fictionnel de l'utilisateur entrera de plus en plus en conflit avec le caractère moins fictif du petit agriculteur (ou du détaillant de pesticides respectivement).

Introduction

Over the past decades, small-scale farmers in India have increasingly been seen as a promising user group for digital technologies. However, figuring out what these farmers expect from digital technologies, if anything, is an ongoing issue. To mention a prominent example, over the second half of the past decade the Indian government, under the auspices of Prime Minister Narendra Modi, has launched several mobile apps for small-scale farmers.[27,28] Broadly speaking, these apps were intended to increase the productivity of Indian agriculture through the provision of information on "weather […], market prices, agro advisories, plant protection, [or] IPM practices."[29] Yet despite the Indian government's best efforts, it remained contentious whether these apps were actually being used by farmers as they were supposed to be. Analyzing the use of one of the apps in the federal state of Chhattisgarh, for example, agronomists found that 28 percent of the farmers surveyed considered the app "very useful" (p. 272), while 54 percent noted a "medium level of usefulness" (ibid.), and 12 percent reported a "low knowledge gain" (ibid.). Looking at a different state, and somewhat more critical in tone, a popular news website commented that "farming apps are almost useless in many parts of Uttar Pradesh, where only 37 per cent households have electricity connections."[30] Agricultural activist Suresh Ediga takes an even more critical stance, arguing that "[d]espite the huge government outlay on these apps, they are practically worthless because they don't meet the standards of

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[27] Vasudeva, V. (2015, December 24). *Agriculture ministry launches two mobile apps for farmers.* The Hindu. https://www.thehindu.com/news/national/agriculture-ministry-launches-two-mobile-apps-for-farmers/article8022495.ece

[28] Inc42. (2021, March 16). *PM Narendra Modi launches Kisan Suvidha app for farmers.* https://inc42.com/flash-feed/narendra-modi-kisan-suvidha-app/

[29] Department of Agriculture & Cooperation,Ministry of Agriculture, Government of India. (2022, September 19). *Kisan: Downloads mobile application.* https://mkisan.gov.in/downloadmobileapps.aspx

[30] Firstpost. (2017, June 25). *Narendra Modi govt's agriculture apps mean little to farmers in dark UP village.* https://www.firstpost.com/india/narendra-modi-govts-agriculture-apps-mean-little-to-farmers-in-dark-up-village-3743675.html

excellence that could have helped farmers in distress," instead, he continues "they remain mere e-governance show pieces of no practical use."[31]

The point of this example is not to evaluate the extent to which these criticisms hold true or not. Rather, it is meant to illustrate that understanding the needs of Indian farmers and translating this understanding into an app that these farmers are tempted to use is a complicated endeavor, even for an actor as powerful and resource-rich as the Indian government. Keeping this difficulty in mind, this chapter explores how the agtech startup FLORA goes about this task, that is, how it generates knowledge about existing or potential PHYTØ users so as to inform the design of the app correspondingly.

To explore this question, the chapter combines two bodies of literature. First, I draw inspiration from debates of STS-informed sociologists and anthropologists examining the reciprocal interaction between designers and users of technologies, also often referred to as the designer-user interface (e.g., Akrich, 1992; Woolgar, 1990). Within these debates, the chapter singles out Akrich's (1995) notion of "user representation techniques" as a sensitizing concept that can help trace how developers of emerging technologies—as in the case of this chapter FLORA—produce knowledge about their targeted users. Second, given that the technology at the heart of the chapter is a mobile app, the chapter borrows additional analytical sensitivities from a more recent strand of media studies scholarship commonly subsumed under the label of "app studies" (e.g., Dieter et al., 2019; Morris & Murray, 2018). These sensitivities are, as already alluded to in the introduction to this thesis, a sensitivity to the "mundaneness" and a sensitivity to the "multi-situatedness" of apps—two aspects that have a great influence on the range of user representations that can be generated with respect to and by means of apps. By bringing these two strands of literature together, this chapter poses the following question: What techniques does FLORA use to create representations of PHYTØ users, and how does the startup reconcile the different user representations that these techniques generate into a coherent understanding of its users?

In response to this question, the chapter argues that FLORA manages to keep up a coherent representation of small-scale farmers as PHYTØ users by continuously generating and reconciling user representations at a distance and in the field. More specifically, the chapter

[31] TheNewsMinute. (2017, May 14). *Are Modi govt's snazzy Kisan apps really helping the Indian farmer?* https://www.thenewsminute.com/article/are-modi-govt-s-snazzy-kisan-apps-really-helping-indian-farmer-62001

argues that within FLORA a dominant user representation prevails, which portrays PHYTØ users as a growing group of farmers and pesticide retailers who recognize the practical benefits of the app and use it accordingly, and that user representations that deviate too much from this dominant representation are either aligned with it using various strategies or, should this not be possible, neglected.

The chapter presents this argument in three sections. The first section reviews existing research on designer-user interactions and mobile applications to further elaborate on the analytical problem of the chapter. The remaining sections examine how FLORA generates and reconciles user representations in its daily work. Section two examines some of the user representation techniques that FLORA performs at a distance, and how they unfold a relatively large influence on the day-to-day operations at the startup. The third section then looks at some of the user representation techniques FLORA employs in the field and describes how the assigned personnel aligns them with the startup's dominant user representation. The chapter closes with a conclusion that summarizes its main findings and interprets them within the general question of this dissertation.

4.1. The multiple ways of representing users of an agriculture app

4.1.1. Examining designer-user relations via user representation techniques

While users used to be viewed as passive recipients of technologies for a long time, from the late 1970s onwards—beginning among economists (e.g., Hippel, 1988; von Hippel, 1976) but quickly transcending these disciplinary bounds—an increasing number of voices were raised arguing that users play a more active role in technological design processes. While there was broad consensus among these researchers that users shape the design of technologies in one way or another, their views differed as to how exactly this shaping takes place. This section presents some of the responses formulated by STS-inspired sociologists and anthropologists. They will serve as a conceptual basis to further scrutinize the designer-user interface in the development of agriculture apps.

One entry point to understanding STS-informed debates concerned with designer-user relations is an article by Woolgar (1990) in which he examines how a company that manufactures computers interacts with the users of these computers. The argument that Woolgar advances is that the employees of the company "configure" the user. By this he means that the employees, in their daily work, engage in a process of "defining the identity of putative users, and setting constraints about their likely future actions" (p. 59). Woolgar suggests the metaphor of the “machine as text” (ibid.), implying that developers of technologies should be considered as “writers” and users as “readers.” To put it in his words, “the machine text is organised in such a way that ‘its purpose’ is available as a reading to the user” (p. 68). In developing this argument, Woolgar pays particular attention to how the company’s employees imagined the users of their computers and how they conducted “usability trials,” in which participants, simulating to be users, interacted with the computers. As he stresses, in these trials, the shells of the computers become the symbol of the relationship between the company and the user in that the employees conducting the trials know the machine inside and out whereas the participants “have a configured relationship to it” (p. 89). Even though Woolgar acknowledges that user configuration “occurs in a context where knowledge and expertise about users is socially distributed” (p. 59), his study was criticized for not paying enough attention to the agency of users themselves in shaping this distributed process.

An influential expansion of Woolgar’s study comes from Mackay et al. (2000). As they put it, “the designer-user interface is more complex than suggested by Woolgar’s work” (p. 753). Put differently, they stress that Woolgar has provided “an important basis for studying how users are imagined in the development of a new technology” (p. 739) while largely neglecting “the work of users in technology development” (ibid.). Against the backdrop of this criticism, they analyze a case revolving around a method for the development of computer systems called “Rapid Application Development” (RAD) and derive four extensions of Woolgar’s conceptualization of designer-user relations. First, they argue for a more symmetrical approach to configuration that pays equal attention to processes of “encoding” (what Woolgar equates with “writing”) and “decoding” (what Woolgar equates with “reading”), underlining that Woolgar has almost exclusively analyzed the former. Second, they argue that “configuration is not a one-way process” (p. 739), stressing that while there is no doubt that designers configure users, “designers, in turn, are configured – by both users and their own organizations” (ibid.). Third, alluding to Woolgar’s emphasis on computer shells, they argue that the boundary between designers and users is far from fixed or given, but instead “fluid, negotiated, constructed, managed and, indeed, configured” (ibid.). Fourth, they argue that analyses of the designer-user interface should not be limited to the sites where technologies are designed and produced but consider “broad actor networks – which extend beyond the confines of the designing organization” (ibid.). With these four extensions, they anticipate much of what Nelly Oudshoorn and Trevor Pinch (2005) would later call “a methodology that takes into account the multiplicity and diversity of users, spokespersons for users, and locations where the co-construction of users and technologies takes place" (p. 24).

Another crucial perspective on designer-user relations that is very similar to that of Mackay et al. (2000) but uses a different conceptual repertoire comes from Akrich (1992). In an analysis of three separate "technology transfer" projects from France to various African countries, Akrich develops the argument that when designers develop a technology, they "inscribe" their worldview (e.g., anticipated preferences of users, political ideas, economic targets) into the technical fabric of the new object. The result of this process is what Akrich calls a technological "script," that is, an "attempt to predetermine the settings that users are asked to imagine for a particular piece of technology and the pre-scriptions (notices, contracts, advice, etc.) that accompany it" (p. 208). Nevertheless, and this is where the difference with Woolgar (1990) and the commonality with Mackay et al. (2000) lies, Akrich (1992) emphasizes that while users may adhere to the roles that designers have defined for them, they may just as well ignore them or define new roles for themselves thus calling the entire innovation into question. As she puts it:

> "To be sure, it may be that no actors will come forward to play the roles envisaged by the designer. Or users may define quite different roles of their own. If this happens, the objects remain a chimera, for it is in the confrontation between technical objects and their users that the latter are rendered real or unreal" (p. 208).

The methodological premise that Akrich derives from this insight is that when studying designer-user relations analysists need "to go back and forth continually between the designer and the user" (pp. 208-209), that is to say, "between the designer's projected user and the real user, between the world inscribed in the object and the world described by its displacement" (p. 209).

This consideration regarding the continuous confrontation between designers' vision of users and actual users in the development of new technologies equally forms the basis for another text by Akrich (1995) that is central to the problem of the present chapter. In said text, Akrich suggests to examine designer-user relations on the basis of "user representations." As Akrich points out, developers of technologies "are from the start constantly interested in their future users" (p. 168) and consequently "[t]hey construct many different representations of these users and objectify them in technical choices" (ibid.). To provide an example of what Akrich means by user representations, one of the three cases she analyzes is a company that produces a "domestic computerized system known as 'Securiscan'" (p. 169) with "a number of applications ranging from house-surveillance to programmed heating" (ibid.). Inside that company diverse user representations such as "the gadget-lover," "the do-it-yourself addict," "the person preoccupied with security," "the computer specialist," or "the middle-to-high income earner" co-exist. The construction of such user representations, Akrich argues, is achieved through so-called "user representation techniques." She distinguishes two different kinds of user representation techniques. On the one hand, "*explicit techniques*, based on special skills or qualifications in the area of defining or interpreting consumer representations" (p. 169) such as market surveys, consumer testing, and feedback discussions. On the other hand, "*implicit techniques*, which rely on statements made on behalf of the user" (ibid.) such as designers acting as model users (Akrich calls this "I-methodology") or external specialists anticipating the needs of users.

In light of these considerations, the core argument of Akrich's article is that the problem for designers "is not so much devising new user representations, for there are many of them already," (p. 168) but finding "methods for coping with the many existing representations, so that they ultimately converge in a way combining different representations and enabling the initial development programme to go forward" (ibid.). It is at this point that Akrich's 1992 and 1995 articles come full circle: the reconciliation of co-existing user representations must be understood as a process in which users may play an active role by, for example, not behaving according to a user representation that the developers of the technology have generated beforehand and tried to inscribe into a design element. In the three cases she analyzes, Akrich identifies three strategies through which designers perform this reconciliation. To stick with the previously mobilized example of Securiscan, Akrich summarizes the company's strategy as a strategy of "delegating [the] reconciliation of representations to intermediaries belonging to established socio-technical networks" (p. 178). The developers of Securiscan saw themselves confronted with numerous coexisting user representations that resulted from various techniques they had used to learn about those users. The consequence that the developers of Securiscan drew from this was that they abandoned their original plan to market the technology through supermarkets and hired intermediaries who not only sold the technology but also installed it and took over "necessary adjustments between user and system" (p. 180). As Akrich puts it, "Securiscan designers had to satisfy just as much the user wanting to run his heating system with optimum efficiency, for example, as the one who is afraid of burglars" (ibid.), for which a coached intermediary was a better fit than a supermarket.

This chapter draws much inspiration from Akrich's study. It aims to make a list of some of the user representation techniques that FLORA mobilizes to get an idea of PHYTØ users. Moreover, it aims to understand how some types of user representations prevail over others within the startup. The next section looks at a supplementary body of scholarship to reflect more closely on the analytical challenges of studying user representation techniques in the case of a mobile app.

4.1.2. Accounting for the multi-situatedness of apps

Media scholars in particular have carried out a great deal of pioneering research on apps over the past decade. Although "the user" is not its central object, the app studies literature provides important insights regarding app use that offer some further analytical sensitivities to address the problem of this chapter. More specifically, these sensitivities are a sensitivity to the "mundaneness" of apps and a sensitivity to the "multi-situatedness" of apps—two characteristics that have a great influence on the range of user representations that can be generated in relation to and with the help of apps, and on how to study them.

As Morris and Murray (2018) note apps are to be seen as "the latest iteration of the software commodity" (p. 4), which puts them in a lineage with technologies like punch cards, floppy discs, hard disks, or CD-ROMs, to name just a few examples. They argue however that "apps are a form of software packaging, presentation, distribution, and consumption that significantly shifts users' relationships with software and their understanding of what software does and can do" (p. 6). The main reason for this app-induced shift in the relation of users to software lies in the "mundaneness" of these emerging technologies. As they suggest elsewhere, apps should be considered "mundane software" (Morris & Elkins, 2015). By this, they mean that apps are supporting more and more everyday activities (e.g., calculator apps used for grocery shopping, or banking apps used for online transactions), but also that apps are increasingly insinuating themselves into routines and habits of everyday life (e.g., self-tracking apps that influence how many steps people walk per day). As they put it, "[t]oday software is literally in the pockets of millions of users worldwide" resulting in the fact that "[n]ow more than ever, users delegate a vast swath of everyday activities to highly packaged and curated software on mobile devices" (p. 8).

This mundaneness of apps, app studies scholars contend, has important implications for how these technologies should be studied. This is brought to the point very clearly in a study by Dieter et al. (2019), in which the authors propose a methodological agenda for what they call "multi-situated app studies" (p. 1). As they argue, the need for such an approach stems from the empirical challenges posed by the simultaneous mundaneness and infrastructural embeddedness of apps on the one hand, and their tendency to transform depending on the socio-technical situations in which they are observed on the other. To put it in their words:

> "Despite their growing importance, apps pose empirical challenges for media research because of their tendency to move into the background while remaining thoroughly entangled with data-intensive infrastructures and the economic models of platforms. Apps are designed to perform as concrete software objects but are continually transformed […] through interactions with diverse socio-technical situations." (p. 1)

To fully comprehend the latter point of this quote, it is important to clarify what the authors mean by "socio-technical situations" or the "multi-situatedness of apps" (p. 9) respectively. As already touched upon in the introduction to this thesis, the authors distinguish their proposed methodology from Marcus's (1995) seminal methodological proposal of "multi-sited ethnography" by emphasizing that their aim is not so much "to 'follow the thing' [as in their case, the app] across multiple sites or locales" (Dieter et al., 2019, p. 2) but rather to study a given app in "multiple infrastructural settings" (p. 1) or "app situations" (ibid.). To do this, they propose four methodological entry points emphasizing that, in theory, one app could be studied through all of these entry points simultaneously. These entry points are "app stores," "app interfaces," "app packages," and "app connections," although the analysis of apps is of course not limited to these four entry points.

In short, this chapter strikes a middle ground between Marcus's (1995) focus on following things, in this case an app, across different sites, and the focus of Dieter et al. (2019) on the socio-technical situations in which apps are embedded. The binding link here, as the chapter will make clear, are the various techniques of user representation that FLORA mobilizes to get an idea of its users. The methodological premise of this chapter is that some of these techniques are better observed on a screen and others are better observed in the field, that is, in the sites where apps are used—or in a combination of both.

4.2. Representing users at a distance

The first important group of techniques through which the FLORA team generates representations of PHYTØ users are techniques that operate at a distance, that is, originating from the offices of FLORA or cooperating organizations. In this section, three of these techniques are analyzed, namely the narrative mobilization of large groups, general performance metrics, and so-called "community metrics." As this section will show, these techniques yield different user representations. However, most of these representations gravitate towards a representation of PHYTØ's user base as a heavily growing group of people who use the app in a self-evident way. This user representation will henceforth be described as FLORA's "dominant user representation." Nonetheless, the section also shows that the analyzed techniques sometimes generate user representations that deviate from the dominant user representation. As will be shown, for such situations the FLORA team has developed a repertoire of strategies to align deviant user representations with the dominant user representation.

4.2.1. Narrative mobilization of large groups: Simultaneously "accessible" and "monetizable" users

A first important technique FLORA uses to remotely create representations of PHYTØ users is the narrative mobilization of large groups that are supposed to represent PHYTØ (or MERCHANT) users. This user representation technique can work through different media such as texts, videos, or audio recordings. This subsection analyzes the example of the appearance of one of FLORA's co-founders on an entrepreneurial podcast. I show how the podcast provides a setting for the co-founder to narratively construct two representations of PHYTØ users as two large, homogenous populations (Indian farmers, Indian pesticide retailers) that the startup can both "access" and "monetize" in an unproblematic manner via PHYTØ—two user representations that sets a strong incentive for investors.

In February 2021, FLORA's CEO was a guest on a popular Indian entrepreneurship podcast. After a couple of introductory words, the conversation between the podcast host and the CEO quickly turned to the topic of the largely untapped economic potential of India's agricultural technology sector and how FLORA might be able to exploit it. More specifically, invoking a report by the consulting firm Ernest & Young, the podcast host excitedly summarized the scope of the markets that he believed PHYTØ would be able to tap into:

> "I was reading this report[32] from Ernest & Young. The agri-tech business in India itself is a potential 24-billion-dollar market. So, the first pain point is there is volatility in input prices,

[32] Pahwa, A. (2020). *Agritech - towards transforming Indian agriculture.* Ernest & Young. https://assets.ey.com/content/dam/ey-sites/ey-com/en_in/topics/start-ups/2020/09/ey-agritech-towards-transforming-indian-agriculture.pdf

and the input selection is suboptimal, and the potential market is somewhere in the range of 1.7 billion dollars. And then there is another pain point, which is limited access to technology for efficient cropping, which is a 3.5-billion-dollar market. This is where your solutions really fit in […]. Then there is another pain point which talks about uneven quality and lack of large-scale testing 3-billion-dollar market. Inefficient post-harvest-supply-chain […] 12-billion-dollar market. Lack of access to financial solutions 4.1-billion-dollar market [laughs]. I think that's quite a bit if you have the farmers on your side."

While much of the preceding quote is simply a paraphrasing of the Ernest & Young report, the last sentence is particularly revealing because the podcast host expresses his view that the most important prerequisite for penetrating the markets outlined by the report is to "have the farmers on your side." In her reply, FLORA's CEO confirms the host's assessment, specifying it a bit further. As she points out, the real challenge in developing these markets is creating "access" to Indian farmers, for which she believes digital technologies are the most appropriate means:

> "It's a huge, huge market and the problem is, there is really no easy access. So, you can't send out a huge bunch of salespeople, or it would be a super huge bunch of salespeople you would have to send out to really talk to the farmers, right? So, that's also the interesting part of it, creating this access, the digital channel to these users."

As this quote highlights, the CEO portrays PHYTØ as a "digital channel" to tap into India's vast farming population. In other words, she frames India's farming population as already existing or realistically attainable PHYTØ users. As she put it in the further course of her conversation with the podcast host:

> "What helped was really that we had quite a fast user growth among users in the beginning and that we could somehow show that we created a new technology for a user group which is more or less untouched in terms of investment, but everyone sees high potential there.

Yet, despite this successful demonstration, the CEO went on to explain, at a certain point it was no longer enough to demonstrate fast user growth among India's farming population. Instead, as the next quote captures, once FLORA's business model began to take shape, the team of the startup increasingly faced the additional challenge of proving that they could "monetize" their growing user base, which required them to expand their conception of the user:

> "The challenge is really to say, okay these people, it might not be that we directly monetize them but rather do it deeper-down in the value chain and a little bit more like a Google type of

> monetization strategy. But the interest was or is still massive and the interest was more like: Okay they might be the first who crack this nut."

As this quote captures once more, the FLORA team's initial plan to monetize PHYTØ with farmers as their sole user group did not work out. Thinking back, the solution that the FLORA team found to this problem was to target pesticide dealers as an additional user group. As with farmers before, the podcast episode served as a space for the co-founder to represent the population of Indian pesticide retailers as a user group that could realistically be reached by her startup in the near future:

> "The retailer becomes our feet on the ground, our face to the farmer, and we can attach more and more services, not only in the app but also with the retailer. And then saying: 'Okay, dear retailer, we can also make you smarter, not only the farmer, but also you and help you to purchase your products and that's in the end where we get our margin from. Our little chunk, what we need to proof that somehow we can monetize the farmer, also if it's not direct but rather indirect."

In short, the second major user representation described by the co-founder in the podcast episode is that of large numbers of pesticide dealers who become PHYTØ users for both epistemic ("smarter") and economic reasons. Moreover, the CEO lets it be known that this user group is not in conflict with the first user group, but is compatible with it, or even supports it.

In sum, the point of this subsection is to show that the narrative mobilization of large groups that are supposed to represent PHYTØ users via digital media such as online articles, videos, or podcasts is a first important technique by means of which FLORA generates user representations at a distance. In the case of the podcast analyzed in this subsection, two user representations stood out, namely the representation of the entire Indian farming population and the entire Indian pesticide retailer population as actual or realistically attainable users which were characterized by the fact that FLORA could "access" and "monetize" them in an allegedly unproblematic manner. As the next subsection will show, these two mutually compatible user representations have strong implications for the daily work in FLORA's offices.

4.2.2. General performance metrics: "Active," "retained", and "boarded" users

Another important technique by which the FLORA team creates user representations at a distance are general performance metrics, where general denotes that the metrics do not refer to a specific feature of the app but to the entirety of the app's features. To monitor these metrics

FLORA mainly relies on the web analytics service Google Analytics. Moreover, the startup uses the SQL-based data visualization tool Redash to turn the results of their measurements into illustrative dashboards. This subsection analyzes three of these metrics, namely "user activity," "user retention," and "boarding," and the three closely related user representations they give rise to. Following on from the previous subsection, this subsection places particular emphasis on showing how it can cause tensions within FLORA if the results of these metrics deviate too much from the user representation of heavy user growth described in the previous section. Referring back to Akrich (1995), the subsection interprets these tensions as examples of situations in which divergent user representations collide and are reconciled in the daily work of the startup.

A first important performance metric that FLORA routinely surveys is "user activity." For explanation, the Google website "Analytics Help" distinguishes between "1-Day Active Users," "7-Day Active Users," "14-Day Active Users," and "28-Day Active Users," while specifying that the corresponding metrics capture "the number of unique users who initiated sessions on your site" in a given period of time.[33] However, as FLORA's CEO explains in another quote from the podcast analyzed in the previous subsection, the user representation that this metric yields is actually not that well suited for the purposes of FLORA due to the rather atypical usage patterns that the PHYTØ application evokes:

> "The standard metrics and KPIs [key performance indicators] you look for in an application are like DAU [daily active users], MAU [monthly active users], and WAU [weekly active users]. However, this never really fit to our user-base, since with the image recognition we are a problem shooting tool. So, you have a problem, you use us, you have three problems in a week, you use us three times. However, then there might be a month where your plants are good, or the harvest is just done and there are no plants on the field. So, you do not have a problem, you will not get out your problem solver. So, it was really difficult for us in the beginning, to find our engagement metrics."

In short, common metrics used by app developers to measure user activity represented PHYTØ users as a rather volatile group. This makes PHYTØ different from other applications like, say, a social media application, where users can be expected to find reasons to use it more frequently. Why exactly these traceable fluctuations in user activity pose a problem for FLORA

[33] Google, Analytics Help. (2022, August 16). Active users: See the number of active users for your site or app. https://support.google.com/analytics/answer/6171863?hl=en#zippy=%2Cin-this-article

becomes clearer in the next quote from an interview with a member of FLORA's product team, in which he describes how they affect the startup's interactions with investors:

> "When the season is over again and the monthly active users drop, when we go from 1.1 million monthly active users back down to 500,000 and you go there and say, 'I want to have money', then they say, 'dude, forget about it'. But if you can always demonstrate engagement and growth, then people will always give you money."

As this quote captures, the fluctuating activity of PHYTØ users primarily became a problem for the developers of the app, because it was a problem for their investors who expected a more continuous "engagement"—which is an umbrella term for the metrics discussed in this subsection and other metrics that quantify user behavior—and "growth."

To diversify their measurements of PHYTØ users, FLORA routinely monitors another metric called "user retention," or "retention" for short. The above-mentioned Google website "Analytics Help" defines retention as the "[p]ercentage of new users who return each day" to a given app or website. For this purpose, all users who open an app or visit a website are assigned a "Google Analytics cookie" and a "Client ID" so that they can be counted as "returning users" during the next sessions. However, as a member of the product team explains in the next quote, what counts as a session and therefore as a returning user is not set in stone:

> "We were right before the founding and Google Analytics simply decided that they would change the way they calculate retention for mobile apps. […] Before that, they counted a session only from 10 seconds onwards. That means we had fewer users but all of them over 10 seconds. That is to say, you practically had 20 percent less users—which we should have known—but those 20 percent that you lost didn't do anything. So, they were obviously under 10 seconds. So, Google changed that and said: People count for a session from the first second onwards. That means we suddenly had 20 percent more users—cool—but retention of course went down because those 20 percent users were all under 10 second sessions. They didn't do anything. That means our weekly retention dropped from 30 percent to 20 percent, from one day to the next."

As this quote shows, while the user retention metric provided FLORA with another tool to monitor and represent the performance of users, it also provided another source of problems. More specifically, as the quote indicates, a change in Google's definition of this metric led to a shifted user representation on the part of FLORA, which made it appear as though PHYTØ users were spending significantly less time using the app—although their actual use of PHYTØ presumably had not changed much. Again, these fluctuations in FLORA's representations of "retained users," so to speak, led to tensions in the startup's interactions with its investors. This becomes clear, for example, in the following interview quote, in which the same member of the product team recalls the days after they found out about Google's change in metrics:

> "Google only communicated this three days later. That means the situation here was tense; we had to explain that to our investors. We had to communicate that the figures are not what they thought they were, that we don't have our shit together. So, you always have to calculate your core-KPIs yourself. You can't tell the investors: Well, Google screwed up. Then they say: Dude, get your shit together."

Thus, as with user activity, the shifted representation of user retention appears to have turned into a problem primarily because it threatened to displease FLORA's investors. Although it cannot be unambiguously inferred from the quote whether this dissatisfaction stemmed from the decline in user retention itself, from the fact that FLORA only identified the reason for this decline three days later, or both, the anecdote provides another insightful example of how the user representations that FLORA generates via its performance metrics may clash with the expectations of the startup's investors—expectations for which, as the previous subsection has shown, the FLORA team is in part responsible itself. As the quote also shows, one consequence the FLORA team has drawn from the experience with Google's retention metric is to increasingly define and calculate its own performance metrics.

An example of such a more FLORA-specific metric is what the team of the startup calls "boarding." In the vernacular of app developers, the term boarding usually refers to the first steps that app users go through in the user interface after installing an app. Typically, these steps involve explaining to users why the app is useful to them, how they navigate the user interface, and what data they need to share to personalize their experience. In the case of FLORA, the boarding process is monitored using three different metrics, sub-metrics, if you will. The first of these sub-metrics is "selected language." In the following quote, a member of the product team explains why exactly the language users choose in the boarding process counts as a performance metric within FLORA:

> "But sometimes it's also kind of good to lose 2 percent. If they then go in with the right language, you've won something […]. For boarding we said: It is very important that people do not choose English. Of the people who choose English, many are in a state in India where we don't have the language yet: Odisha. That means that if we then support this [users not selecting English as language], we improve these KPIs."

In short, the FLORA team has found that many users who chose English as their default language were not really proficient in English, which in turn negatively affected the overall engagement of PHYTØ users. As a consequence, the FLORA team came to regard it as a positive performance indicator when users did not choose English in the boarding process. The second sub-metric that the FLORA team came up with to monitor the boarding process was "boarding completion," which, as the name suggests, refers to the number of users who complete the entire boarding process without opting out. Lastly, the third sub-metric is "location-permission." As with language, in this case too, the FLORA team has made the experience that requesting "location permission" may deter some users. Nonetheless, they began tolerating this "dropout" because they found that it increases the overall engagement of PHYTØ as reflected in other performance metrics.

In summary, FLORA's handling of these three performance metrics shows how in the work of the startup and its extended network, different user representations collide and are reconciled. More specifically, the subsection has shown how the user representations produced by the performance metrics temporarily diverged from FLORA's dominant user representation, and how this led to tensions with the startup's investors. The result of this was often that the FLORA team adjusted its metrics, or at least developed explanations for the divergence, to re-establish coherence between the user representations that these metrics generate and the user representation that their investors have in mind. Put differently, they reconciled divergent user representations to reinstate a dominant user representation of a growing user base.

4.2.3. Community metrics: Not-so-active, "power," and expert users

Another crucial technique through which the FLORA team creates user representations at a distance are performance metrics that relate to a feature called the "community"—an online forum in which users can exchange agricultural knowledge with each other and with agricultural experts. As with the overall performance metrics, the startup uses Redash to visualize the user data that the community generates. As it will be shown, the community metrics produce three primary user representation. First, a representation of numerous not-so-active community users. Second, a representation of a few very active users, that the FLORA team refers to as "power users." Third, a little different in nature, a representation of hired expert users who maintain the community activity. In keeping with the focus of the chapter, the subsection interprets the hiring of expert users as a strategy by which the FLORA team aligns the deviant user representation of “not-so-active community users” with FLORA’s dominant user representation.

To begin with, in a business plan from 2016, when the community was still in its planning stages, the developers of PHYTØ outlined the vision behind this feature by stating that they envisioned to create “a community of interested farmers and gardeners” in which users “communicate and receive expert advice” via a forum and personal messages. As the document continued, PHYTØ would thereby “connect millions of passionate gardeners and be their platform.” As this explanation captures, the FLORA team initially had high expectations regarding the community’s potential to generate users and get them to interact with each other in a more or less self-motivated way (“millions of passionate gardeners”). In addition, it becomes clear that already at that time it was planned to support the activities in the community with additional expert advice.

The community grew alright and counted around 33,500 posts per month in September 2019. Nonetheless, at the beginning of 2019, as I conducted interviews in the offices of FLORA, the realization had already percolated among the team that the use of the community would not be as much of a self-propelled process as they had initially envisioned. As one software developer involved in the maintenance and monitoring of the community explained:

> “They [the co-founders] always compare that with Stack Overflow. Have you ever looked at that or have you ever used that? It’s this site for programmers where you ask for advice and somehow, they want this to be a Stack Overflow for plant problems. And that’s just so unrealistic because that’s a whole different audience. Because these are kind of educated programmers that write in English and we just have farmers that maybe some of them can’t write that well and I don’t know how many languages we have now, fifteen languages. That’s why, yes, the community is not perfect at all.”

As this quote documents, the co-founders of FLORA initially planned that community users would behave like users of a popular question and answer website for professional and amateur programmers that they themselves used in their daily work. In other words, the quote contains a classic example of what Akrich (1995) calls the “I-methodology,” and how it proved relatively unsuccessful in the case of the PHYTØ community. Beyond that, the interviewee cites two possible reasons for what he considers the community’s “not perfect at all” performance: First, he mentions that community users have lower levels of formal education than Stack Overflow users, which may make it harder for them to express themselves in writing. Second, he points out that while the dominant language used by Stack Overflow users is English, community users communicate in fifteen different languages, which implies that their debates are more splintered, and thus more difficult to keep alive.

To incentivize community users to use this feature more frequently, at some point the FLORA team decided to implement a rewards system. The way this rewards system works is simple: For certain actions performed by community users, they receive points that allow them to rise in their community rank, with no upper limit on the number of points that a user can collect. Points are awarded for various actions such as posting a plant-related problem, writing a comment under a problem, "upvoting" other users' posts or comments, or marking another user's comment as the solution to a problem. However, the users of the community did not adopt this rewards system as well as the developers of PHYTØ had hoped for. In the next quote, the employee quoted above illustrates this point by describing an example where users did not use the suggested button to mark certain comments as a solution to a particular problem as extensively as in the case of the developers' role model Stack Overflow:

> "The problem with the solved [button] is simple […]. So, there's no incentive to use it. It's just that with Stack Overflow, it's part of the community that you do that. You know that you get points for doing it, and if you don't do it, if you don't choose a comment that is solving your question, then the other members of the community remind you. I mean, you have to get to the point that people do that, right? [...] So, there has to be a very clear incentive to use it and if there isn't then- [it is not used]."

Once again, it shows how the developers of PHYTØ drew inspiration from Stack Overflow when designing the community but found that the users of the community that they had created behaved differently than expected. In this case, it turned out that the users used the solved button only sparsely. Once more, the interviewee has a possible explanation for this, namely, that Stack Overflow users have more routinized ways of giving and calling for feedback. To be clear, the solved button is just one of numerous examples of how the PHYTØ developers evaluate the activity of community users. Besides it, the FLORA team keeps track of other metrics like the "average answer time," the "comment-count," the "weekly-comment-count by country," the "weekly-post-count by detected language," the "posts with library link," as well as the "posts marked as solved." Community users mostly fell short of the developers' original expectations in all these aspects.

Nevertheless, there are some exceptions among the community users, which the FLORA team refers to as "power users." These power users are the community users with the highest number of points—collected through the activities described above. The interviewee described the importance of these power users to FLORA as follows: “These power users are super important, because these are people who do it on their own initiative and are super active in the community.” As this quote captures, power users are a small group of community users whose activity comes close to the developers’ ideal of how community users should act. As the interviewee continued, there are two main reasons why the FLORA team studies power users so closely. First, because the FLORA team hopes that by closely monitoring these users, they will gain insights into why these users use the community so actively while other users do not. Second, because the FLORA team regularly contacts the best of these power users to recruit them as “community experts.”

In a nutshell, said expert users do most of the work necessary to keep the activity in the PHYTØ community going. An internal document from 2018 with the name “Community Expert Handling” provides an impression of the role attributed to these expert users within the startup. As the document puts it, “[t]he PHYTØ community experts are an important part of the service we offer for our users in the community” specifying that they are usually hired to “accompany a new language release and support us to provide a positive user experience in […] the first weeks until highly active users take over the answering load.” These quotes summarize very well how the FLORA team envisioned expert users as a kind of catalyst to initiate community activities until other users would take over the bulk of these activities. However, as indicated earlier, this plan has materialized only to a limited extent, in that “highly active users” have never really taken over the community which is why the expert users continue to do much of the work that keeps the community feature running.

Besides the converted power users mentioned above, the document goes on to explain that expert users are usually hired through Upwork, with a key requirement being that they bring plant pathology expertise. Zooming in on the actual work of these expert users, the document continues to explain that experts “are representatives of PHYTØ […] and thus should stick to a few quality and style guides”: First, before answering a question, experts are supposed to be sure that they know the disease in question. Second, if they are not sure, they should always ask for additional information. Third, if they can identify the problem, they should always use a “#” to establish a link to the Encyclopedia. Fourth, expert users are instructed to “[w]rite short and to the point answers & recommendations, no longer than 4-5 phrases.” Fifth, they are asked to mainly answer posts in their mother tongue and refrain from using Google Translate. Sixth, they are again advised to respond only to questions concerning symptoms that they know well.

Lastly, the seventh instruction is more technical in nature and consists of a request to enter the answers into a specific text field of the app.

As with non-expert users of the community, the activity of expert users is closely monitored. In fact, the activity of expert users is monitored even more closely than that of non-expert users, since the FLORA team, as captured in the subsequent excerpt of the above-mentioned document, wants to ensure that they are doing the work for which they are being paid:

> "New experts need a person as point of interaction. This person should follow them in PHYTØ and give them regular feedback, especially in the beginning on the style and content of their posts. Experts also check if we're watching them… let them know you're reading their posts, stop them from just replying to posts confirming the other experts' opinion, or just telling people that didn't upload an image to do so. We're not paying them for this."

Hence, unlike non-expert users, expert users are assigned a member of the core team of FLORA who evaluates the quality of their work in the community and calls them to order when it is deemed necessary. Furthermore, as the next quote makes clear, also in the case of expert users, the FLORA team uses performance metrics to monitor their activity, that is, to generate representations of these expert users:

> "We need to check regularly on the posting rates of our experts. Their post/hour rates is tracked in [link to a spreadsheet]. We assume a post/hour rate of 20 posts as goal for all the experts. Yet, as you will see, the rates of the experts vary. Again, some of them are more valuable for their long-time commitment / agricultural experience, some just answer a lot of posts with a pretty standard reply."

As this quote illustrates, the metrics used by the FLORA team to measure the performance of expert users are very similar to those used to measure the performance of regular community users, and even allow them to typify the expert users. In this case, the typification is indicated by the distinction of the user representation of those who are characterized by "long-time commitment / agricultural experience" and those who answer "with a pretty standard reply."

In sum, this subsection has demonstrated that FLORA's community metrics generate three different user representations. First, a representation of many not-so-active community users. Second, a representation of a few "power users," and third, a representation of "expert users." Furthermore, it was argued that the representation of the many not-so-active community users conflicts with FLORA's dominant user representation of a heavily growing user base. As a result, the subsection suggested, the FLORA team began hiring expert users to approximate the activity of the not-so-active community users to that of more active community users.

4.3. Representing users in the field

The second group of techniques through which the FLORA team generates representations of PHYTØ users are techniques that are carried out in the field, that is, at the sites where PHYTØ is used. This section examines three of these techniques namely the narrative mobilization of individuals, "prototype testing," and "card sorting." In contrast to the previously described group of techniques, these techniques primarily serve to produce representations of individual users or smaller groups of users. Most importantly, the section shows that the individual farmers that the employees who perform the aforementioned techniques encounter in the field sometimes deviate sharply from the dominant user representation that was outlined in the previous section. To reconcile these experiences with deviant users with FLORA's dominant user representation the employees of the startup have developed another important strategy. As I will argue, this strategy consists of merging experiences with deviant users with experiences with less deviant users in order to generate final user representations that are more aligned with FLORA's dominant user representation.

4.3.1. Narrative mobilization of individuals: Model users

A first important technique through which FLORA generates user representations in the field is the narrative mobilization of individuals that are supposed to represent PHYTØ (or MERCHANT) users. As the narrative mobilization of large groups, discussed in the previous section, this user representation technique can work through different media such as texts, videos, or audio recordings. This subsection analyzes the example of a range of marketing videos that FLORA has produced to attract small-scale farmers and later pesticide retailers as new users. Based on this, it is argued that the videos narratively construct what could be labeled as "model users," that is users who act exactly as envisioned by FLORA, and who, figuratively speaking, put an individual face to the startup's dominant user representation.

In 2018, FLORA's marketing team uploaded a total of ten videos to YouTube that were targeted at small-scale farmers in India. To produce these videos, members of FLORA's German marketing team had traveled to India to film PHYTØ users on their farms. The videos range in length from 30 seconds to 2.5 minutes and have reached between 2.5 million and 50,000 views by the middle of 2022.

The overall narrative of all ten videos is very similar and can be summarized as follows: Each of the videos begins with a self-presentation of the featured farmer (exclusively men) and a description of how they had major problems with plant damages in the past, whether in diagnostics, pesticide selection, or both. Subsequently, in phase two, so to speak, each of the farmers recounts how they discovered PHYTØ and how the app provided them with all the information they were lacking before. Finally, in phase three of the narrative, the portrayed users share how they are now getting good yields thanks to the app. Besides these narrative similarities, the videos are also very similar in terms of their formal realization. The videos usually consist of two types of shots. In the first type of shot, users are shown standing or sitting on their fields while they recount, each in their own way, the narrative summarized above. Secondly, these interview sequences are interspersed with scenic shots of users' farms; a field of cabbage, a man walking through a rice field, a banana plant blowing in the wind. Besides that, all videos are accompanied by the same, monotonous cheerful music.

To give a more accurate sense of the kind of user representation these videos put into the world, here is an anonymized transcript of the entire voice track of one such video, with a total duration of about one minute:

> "My name is [name] and I belong to [village], in [district]. We grow cabbage here. So, due to pollution, there is infestation of insects on it. When we started using the PHYTØ app, we understood what steps should be taken once an infestation or a disease is noticed. PHYTØ helped us to determine that. It was through this app that we realized the remedial steps for the affected cabbage plant. Before this, we were clueless as how to treat an infested tomato plant. But thanks to PHYTØ, we are succeeding in getting a good harvest. Because, due to this app we can foresee the disease that can affect our crops and understand about its treatment. With the help of PHYTØ app we can click a picture of the affected plant and understand the disease as well as the medicines to be sprayed on it."

As this transcript shows, the video presents a user who suffered from a consequential knowledge deficit in the past ("we were clueless") that he remedied by using PHYTØ, exactly as the app's designers envisioned ("we can click a picture […] and understand")—a user representation that is undoubtedly compatible with FLORA's dominant user representation of a growing user base of farmers who dedicatedly use the app, but, in a way, individualizes it. In the terms of Akrich (1992), the video portrays a "docile user" who follows PHYTØ's script exactly as FLORA prescribes.

A very similar way of representing users can be observed in the videos that FLORA produced to promote its more recent app, MERCHANT, among pesticide retailers in India. I will examine one of these videos, which was uploaded to YouTube in 2020, in more detail. In keeping with the video's target audience, it is set not on a farm but in a pesticide store. More specifically, the video shows a busy pesticide retailer either talking on the phone or glancing attentively at the display of his smartphone. Again, the video is underpinned by upbeat music. In parallel, the following text accompanied by screenshots of the MERCHANT user interface are progressively faded in, demonstrating where the operations described in the text can be carried out in the app:

> "It can be challenging for you to buy products and get reasonable prices. Calling distributors of each company takes a lot of time. There is no proper info about discounts and offers. We have a simple solution for all your problems: Use the MERCHANT app! Purchase all types of agri input products from 45+ top brands! Know the net rate of each product after all schemes! Benefit from quantity schemes as well. Take advantage of a credit line! And get orders directly from the farmers through this app! Upgrade your business and become a MERCHANT!"

Even though in the case of this video the pesticide dealer does not speak for himself, making the user representation of the video somewhat more implicit, in this transcript too one can discern an idealized representation of current or future MERCHANT users who rationally decide that the app offers economic advantages and consequently use it to optimize their businesses. Once again, I do not intend to assess the extent to which this representation is accurate or not. Rather, my point is to show that it is highly compatible with FLORA's dominant user representation of a rapidly growing user base of dedicated farmers and pesticide retailers.

In summary, this subsection has argued that FLORA's narrative mobilization of individuals gives rise to user representations that can be labeled as model users, that is, individual users who use PHYTØ or MERCHANT exactly as the app developers envisioned it in the design process. Furthermore, it was argued that these user representations are not only compatible with FLORA's dominant user representation but further personalize it by equipping it with individual faces. Nevertheless, as the next subsections will show, not all alleged users in the field behave like the model users in FLORA's marketing videos.

4.3.2. Prototype testing: A deviant user

Another technique by means of which FLORA generates user representations in the field are so-called "prototype testings." In a nutshell, prototype testing refers to a user experience ("UX") research method in which users are presented with a prototype of a given technology to study their reactions. During my research stay in India in January and February 2019, I had the opportunity to accompany FLORA's product team while they were performing such a prototype testing involving a new version of PHYTØ. As this subsection will show, the product team came into the testing with a fairly fixed idea of how the participating user should behave, from which the user deviated markedly as the intervention progressed—a deviation that conflicted with FLORA's dominant user representation. The subsection further shows how the product team, in presenting the results of this testing upon their return to FLORA's German headquarters, aligned their experiences with the deviant user in the field with FLORA's dominant user representation.

The prototype testing that I was allowed to observe involved a relatively large group of people: First, it involved two UX researchers from FLORA's German office (hereafter: UX1 and 2). Second, it involved a UX researcher from FLORA's regional office in Western India (hereafter: UX3) who was currently being trained by UX1 and UX2. Thirdly, it involved another employee of the aforementioned office who had previously worked as an agricultural advisor in the region, and who was responsible for recruiting users to participate in the testings as well as organizing transportation (hereafter: EM1). Apart from that, of course, the collective also consisted of the farmer who was to participate in the testing (hereafter: FA1) and me, a PhD student from a Parisian research institute. Since neither UX1, nor UX2, nor myself spoke Marathi, the farmer's native language, both UX3 and EM1 acted as interpreters for everything that was said before, during, and after the testing.

On the morning of the testing, we drove two cars for about an hour from FLORA's regional office to the farm of the participant. The actual testing took place in an inconspicuous spot, an earthen path under a few trees between two fields on which one could make out small plants, perhaps beets. After the farmer had led us to the place, the group sat down in a circle on the dry ground and began almost immediately with the testing. UX1, who conducted the testing began by thanking the farmer for his participation and by informing him that it would take about half an hour (which turned out to be an hour in the end). UX1 then asked FA1 if he had used PHYTØ before, to which FA1 replied in the affirmative. After it was affirmed that FA1 was indeed a user, UX1 continued with a more detailed explanation of the testing procedure and how the farmer should behave during it:

> "So, I would like you [EM1] to tell him that we are going to show him today a new app, a new version of PHYTØ, which is not fully functioning. It is a bit different to what he has seen before. So, it might occur that he is trying to click on something, and it does not work. That's totally okay. If this happens, I would like him to tell me what he expected to happen. Okay, and I will give him this app to use, and as he is using it, I want him to speak out loud and tell me what he

is thinking, why he is using it the way he is using it. And in order to take notes later in the office, I need to record the screen, so we can look at it later in the office and take notes. Is this okay with him?"

These instructions are revealing, because they provide a clear impression of how FLORA's UX researchers, in preparing the testings, envisioned the users who would participate in these testings. More specifically, as the quote shows, they envisioned users who were well acquainted with the app, used it in a routinized manner, and were able to verbalize their thoughts while doing so. Similar to the previous subsection one could say that the UX researchers expected to interact with "docile users" (Akrich, 1992) whose thoughts and touches could be translated more or less seamlessly into actionable insights via voice and display recordings.

As the following excerpt from the conversation at the beginning of the prototype testing shows, the user initially behaved as expected:

UX1:	I just need to start the recording very quick. Okay. Three, two, one. So, before clicking on anything, I would like him to imagine that he just recently downloaded PHYTØ, this app, and this is the first screen you see after opening it.
EM1/FA1:	[–][34]
UX1:	And, like, what does he think he can do on the screen?
EM1/FA1:	[–]
UX1:	Hm?
UX3:	He will select the crops.

The prototype testing initially unfolded quite as planned in the instructions that UX1 had presented at the beginning. The prototype was running, she phrased her question, EM1 translated the question, and UX3 translated a succinct answer by the farmer. The prototype testing continued in this planned manner for about 20 minutes. The interfaces that the PHYTØ prototype displayed to the user changed as he clicked through the app, but the way UX1 asked her questions remained unchanged. To provide another example:

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[34] This sign indicates when participants of the prototype testing have spoken in Marathi, which neither the members of the German FLORA team nor I understood.

UX1: Okay, imagine that this is your camera now, and you are seeing wheat, so this is like- this picture-

EM1: [–]

UX1: And you want to take a picture of it.

EM1: [–]

UX1: How would you proceed?

EM1/FA1: [–]

UX1: Mhm.

EM1/FA1: [–]

EM1: He is saying, I can take a photo, tab this photo button, take a photo, and it shows the information.

UX1: Can you do this [tab the photo button]?

EM1: [–]

UX1: Can you- can you go through the screen and explain to me what you are seeing there?

UX3: [–]

FA1: [–]

UX3: Name of the disease.

FA1: [–]

UX3: The name of the disease, the details of the disease, the impact that it is going to have on the crop, and organic and chemical fertilizer information.

Once again, the prototype testing proceeded as planned by the UX researchers: UX1 began with a brief contextualization of the interface displayed to the user, and then prompted him to take a picture—as prescribed by the interface—while describing his actions. Once the user had pressed the photo button, she formulated a follow-up question asking him, as many times before, to describe what he saw on the screen. As in the first example, UX3 translated the farmer's answer in brief words.

Then something unplanned happened. As UX1's questions neared the end, EM1, who was actually only responsible for making contact with the farmer, arranging transportation, and interpreting, spontaneously took control of asking the questions, as recorded in the next excerpt:

EM1:	[To UX1] Now I can ask a few questions. This information you see, you think every farmer can read this information-
UX1:	Let me ask the questions, okay?
EM1:	-because what I think, last time we were-
UX1:	We can talk about this. Let's talk about this later.
EM1/FA1:	[–]
EM1:	Other farmers using these notes. No one can read this information.
UX1:	Let me ask the questions, okay?! So, if you take a picture of your crop, and get the right disease, what kind of information would you like to see?
EM1/FA1:	[–]
EM1:	He says, what I need if I had a pest, I spray. I get record. And how it becomes good, the quality, so I can get high price.
UX1:	[to UX3]: Did you understand what he said?
UX3:	So, he said, he wants to know how he can increase the quality of his products, so that he, when he goes to the market, gets more price compared to the farmers.

As this excerpt illustrates, EM1, who had facilitated similar prototype testings before, was dissatisfied with the way UX1 asked the questions during the prototype testing, so he announced to her that he would now direct some questions to the farmer. Initially, UX1 protested this by implicitly pointing out to EM1 that asking the questions was not his responsibility ("Let me ask the questions, okay?"). However, after EM1 informed her that the farmer present and other farmers he had previously been in contact with often did not understand the texts of the app ("No one can read this information"), UX1 seemed to give in, as she moved to a different style of asking questions. More specifically, she stopped asking the farmer what he was thinking while he was performing one or another action in the user interface of the prototype and moved on to asking him, in an interview-like fashion, what information he would like to see in the app, to which she received a relatively comprehensive response.

As the prototype testing progressed, this more interview-like or even conversational interaction between UX1, EM1, and FA1 continued. As the next excerpt records, FA1 even went so far as to openly criticize some elements of PHYTØ, with the interpreting assistance of EM1.

UX3:	He [EM1] is asking that you have one page [i.e., screen], and if you click the photo, there is a disease. What do you want on that one page?
EM1/FA1:	[–]
UX3:	Number of days in which it can get cured.
EM1/FA1:	[–]
UX3:	He wants to know in how many days the disease can be controlled or cured.
UX2:	Okay, but this is when the disease is detected, right? But what happens? Sometimes we are not one hundred percent sure that the disease is correct, so we show him different options. How would he like to see that?
EM1/FA1:	[–]
UX3:	He wants the exact information and the correct information.
UX1:	Like the other farmer said the same yesterday.
EM1:	He say-
UX1:	They can't choose because they don't know.
EM1:	He says, he is clicking the photo, and it is not showing the proper disease, then you can go to the community.
FA1:	[–]
UX3:	He does not want to guess.
UX1:	I know.
UX2:	So, he can't compare? He can't compare and choose one disease?
EM1:	Farmers say, we don't want to compare. We want the exact answer.

As this quote illustrates, the unplanned behavior of EM1 that was exhibited in the previous two excerpts resulted in a lively conversation between all parties involved in the prototype testing. This conversation, quite different from the highly formalized prototype testing before, gave FA1 the opportunity to express his dissatisfaction with several characteristics of PHYTØ. In the case of the excerpt above, his dissatisfaction is directed, for example, at the fact that PHYTØ does not indicate how long it will take to cure a given plant damage, and at the fact that the app displays a list of possible diseases to farmers in the case of inconclusive diagnostic results, asking them to make the final decision. As this excerpt also illustrates, the "deviant user," after which this subsection is named, is a collective performance with EM1 and FA1 as its main protagonist, and, as should have become clear, a collective performance that is anything but commonplace. In other words, it took a complex chain of events for the farmer to, more or less freely, express his opinion about PHYTØ's user interface.

Upon their return to Germany, the product team made an effort to present the results of the prototype testing in a PowerPoint to the rest of their team. To do this, they summarized their experiences during the prototype testing discussed in this subsection with the experiences they had made during a few other prototype testings they had conducted during the trip in a few bullet points on a handful of slides. On a formal level, they divided their slides according to the different "screens" of the app that the participating farmers were guided through during the testings, such as "Onboarding – Crop selection," "Home screen," "Disease screen," or "Pesticide detail screen." Then, for each of these screens, they listed some bullet points describing aspects that the participating farmers liked or understood well and aspects that the participating farmers disliked or did not understand well. To give an example, with regard to the "Home screen" they point out that "Buttons for Crop Scan, Seed selection, Fertilizer calculator and Pest and diseases (Encyclopedia) are clearly understood and noticed by participants" and that "Users appreciate that these buttons are aligned sequentially (Seeds, Fertilizers, Pests and diseases)." However, they also identify a missing element stating that "Weather info is needed for any kind of agric. decision-making." Another example is provided by the slide concerned with the "Pesticide detail screen" that mentions "Information is very useful and covers almost everything the farmer is looking for" while criticizing that "Time of day of application is missing" and that "Brand names are preferred over chemical agent." On the slide "Additional insights" one can also find a result that can clearly be traced back to one of the prototype testing situations that has been documented in this subsection where it states, "In case a disease is not clearly identified, users don't feel able to choose the right match out of the list provided by the system." As the listing of these examples illustrates, the final user representation that the product team drew from the prototype testings collectivizes the experiences they had with the individual farmers in the field which made individual deviations from FLORA's dominant user representation, such as the utterances of EM1 and FA1 that were described in this subsection, less salient. In other words, it reconciled the product teams experiences with the deviant user with FLORA's dominant user representation.

This subsection has shown that the farmers that the FLORA team encounters in the field may deviate from FLORA's dominant user representation. More specifically, the subsection has argued that such deviant users are to be understood as collective performances involving both farmers, but also other actors associated with the startup. Upon their return to Germany, the chapter further demonstrated, the responsible employees did not share all of their experiences with the deviant user one-to-one with the rest of their team.

Rather, they merged the experiences with the deviant user with insights they had gathered during other prototype testings and generated a final user representation that was more aligned with FLORA's dominant user representation. This collectivization of experiences made in the field can thus be regarded as another strategy through which the FLORA team reconciles divergent user representations and thus maintains a relatively coherent user representation within the startup.

4.3.3. Card sorting: Two non-users and one user

Another technique by which FLORA generates representations of PHYTØ users are so-called "card sorting sessions." Just like prototype testing, card sorting is a method used by FLORA's product team to study the "user experience" of PHYTØ users in the field. During my research trip to India, I had the opportunity to observe three such card sorting sessions conducted by the product team. Based on the observational data that resulted from this, this subsection describes how in conducting these card sorting sessions the product team unexpectedly saw itself confronted with several non-users and how, upon their return to FLORA's offices, the card sorting method allowed them to transform these encounters with non-users into representations of PHYTØ users. As in the case of prototype testing, this is interpreted as a practice of aligning experiences with users who deviate too much from FLORA's dominant user representation with said user representation.

In February 2019, three employees of the product team from FLORA's German office together with two employees from FLORA's regional office in Western India set out from the regional office to conduct several card sorting sessions with farmers from surrounding villages. The three employees from the German office were UX1 and UX2, who already appeared in the previous subsection, as well as the head of the product team. From the side of the regional office, they were again accompanied by EM1 and UX3. Apart from permanent FLORA employees, the delegation was accompanied by a student from a nearby agricultural college who was hired to act as an interpreter (hereafter: IN1), and again me.

To provide some background on the card sorting method: In a PowerPoint presentation that the product team held in front of the rest of the German FLORA team upon their return to German, they described card sorting as a "UX research methodology used to help design or evaluate the information architecture of an app." They also summarized the main question they were hoping to answer with this method as follows: "What information do our users want to see and where do they want to see them?" Beyond this general question, UX1 and UX2 had planned a precise procedure for the card sorting sessions. As they explained it to their colleagues "[i]n a card sorting session, participants organize pre-named cards into groups that make sense to them and […] label these groups." Getting a little more specific about the card sorting sessions they had carried out, they stated that they had "asked participants to organize cards with content of PHYTØ into groups that make sense to them" before inviting them to "name each group they created in a way they feel accurately describes the content." In total, the UX researchers had prepared 55 cards, which were kept quite simple. They were white square pieces of paper on which a word or group of words corresponding to a theme in the PHYTØ interface were printed (e.g., "Weather," "My crops," "Other crops," "Crop Scan," "Organic fertilization information," "Chemical fertilization information," "Fertilization calculator," "Seed varieties"). Below this inscription each card had another printed inscription that translated the words on the card into the native language of the expected participants, which in the case of the participants discussed in this subsection was Marathi.

The three card-sorting sessions I was allowed to attend all began with the UX researchers reading out a few opening remarks to prepare the participants for what was about to happen. While the first and third card sorting sessions were moderated by UX1, the second was moderated by UX3. UX2, who was senior to the others, sat on the sidelines taking notes and intervening now and then when something did not go according to her liking. Considering that neither UX1 nor UX2 spoke Marathi, everything they said in the course of the card sorting sessions that was intended for the ears of the farmers was simultaneously translated by IN or UX3, who took spontaneous turns. The opening remarks always began with the UX researcher in charge thanking the farmer for taking the time to participate in the card sorting session. Afterwards, participants were informed about the goal of the UX intervention, namely that the UX researchers intend to redesign PHYTØ in a way that would enable "real users" to find "the information they need" more easily. After that, the actual sorting was initiated by inviting the farmers to spread out the cards in front of them and group them "based on which information

[they] think belongs together." As a final instruction, each participating farmer was encouraged to think aloud as he proceeded with the sorting.

Contrary to the FLORA team's expectations, the farmers who were to participate in the card sorting sessions that day differed markedly from the participants that UX1 and UX2 had in mind when they were planning the intervention. More specifically, EM, who was told at relatively short notice that he was responsible for recruiting participants, had had difficulty finding PHYTØ users who were willing to take the time to participate in one of the card sorting sessions. Yet, as he explained to me during a break, because he still wanted to organize participants for his German colleagues' UX research endeavor, he had recruited farmers from the network he had from his time as an agricultural extension agent. The trade-off, however, was that not all of these participants were PHYTØ users in the strict sense. In fact, as will become clearer, two of the farmers participating in the card sorting sessions that day considered themselves non-users, while only one participant described himself as a user, albeit a sporadic one—a circumstance that only gradually became apparent while the card sorting sessions were already underway. As an example, the following excerpt from the transcript of the first card sorting session captures how it became clear that the putative user had in fact never heard of PHYTØ before:

UX 1:	What smartphone apps does he use?
UX3/FA1:	[–]
UX3:	He doesn't use any. He doesn't have a smartphone. His children have a smartphone.
UX1:	Why not?
UX3/FA1:	[–]
UX3:	He likes the old phones.
UX1:	I need to know what he knows about PHYTØ.
IN1/FA1:	[–]
Me:	What are they talking about?
UX3:	He is curious what PHYTØ is. He is confusing it with some seed company.

As this excerpt illustrates, UX1 had not expected to be confronted with a non-user and was accordingly taken aback. Nonetheless, rather than canceling the card sorting session, she simply adjusted her research question on the fly. The following continuation of the above conversation illustrates this adjustment even clearer:

UX1:	This app is made for farmers like you. Can you group the information that you think belong together?
UX3/FA1:	[–]
UX3:	He does not understand.
UX1:	He shall group them, how they make sense to him. There are no right or wrong answers. And if there are any cards that do not interest him, he shall put them aside.
UX3/FA1:	[–]
UX3:	He is saying that he did not have so much exposure to the app and that he will-
UX1:	That's not a problem.
UX3:	And he will sort them like he uses them in the field.

What makes this conversation so interesting is that it shows how UX1 spontaneously switches to addressing the participant not as a user, but as a farmer. Instead of pursuing the originally formulated question, "What information do our users want to see and where do they want to see it?" the confrontation with the non-user causes her to adapt the question of the card sorting session. More specifically, after realizing that she was indeed talking to a non-user, she devoted herself to the broader question of what information farmers—not users—wanted to see and where they wanted to see it. A similar situation occurred with the third farmer who was to take part in the card sorting that day:

UX1:	[Addressing both the farmer and his friends and relatives present] Who is using a smartphone?
IN1/FA1:	[–]
FA1:	[FA1 affirms the question with a gesture of his hand]
UX1:	What applications are you using?
IN1/FA1:	[–]
FA1:	WhatsApp.
IN1:	WhatsApp.

UX1: Alright [Reads out the scripted opening remarks. Since the farmer only uses WhatsApp, she replaces the request that the farmer should group the cards based on his experience with PHYTØ with the request that he should group the cards based on his experience in the field]

While the fact that the participant had never used PHYTØ seemed a little out of the ordinary in the case of the first farmer, the UX researcher had already developed a certain routine by the time she found out that the third farmer did not use the app either. Indeed, as can be seen in the excerpt above, she incorporated a test into the conversation as to whether the participant was a user even before the opening remarks were read, and, when the participant failed this test, adapted the opening remarks and the remaining testing without much hesitation.

As mentioned before, only the second farmer we visited that day identified as a PHYTØ user, albeit only partially. As one of the Marathi native speakers told me, the farmer did indeed use PHYTØ from time to time to identify plant damages, but only the "Crop Scan." Apart from that, the informant continued, the farmer actually had little desire to participate in the card sorting session because he thought it was "pointless" and "boring." However, he had finally agreed because EM1 had offered him free agricultural extension services in return, such as assistance in obtaining a loan from the bank. In short, the second participant could be considered a PHYTØ user, although with some reservations.

This being said, to get to the actual procedure of a card sorting session with a genuine user. As described in one of the PowerPoint presentations they held in front of the FLORA team, UX1 and UX2 see card sorting as a method to "[u]nderstand how farmers naturally think of information related to farming." Consistent with this assumption, in the practical execution of card sorting sessions, they took two primary precautions to keep the presumed translation of farmers' thinking into card arrangements as "natural" as possible. The first of these precautions concerned the space where the card sorting sessions were to take place. More specifically, in the run-up to the card sorting sessions, farmers were instructed to choose an undisturbed corner of their farm and spread a blanket on the floor on which the card sorting could take place. In the case of the first and third farmer, this quiet corner consisted of the floor of their living rooms. In the case of the second farmer, it consisted of a patch of ground in the middle a chicken coop that was currently being built (see Figure 8).

Figure 8: Card sorting session (Source: Photo taken by the author)

As can equally be seen in Figure 8, the UX researchers also placed great emphasis on who was allowed to sit on the blanket. While only the participant, the UX researcher in charge and, if necessary, an interpreter, were allowed to sit on the blanket, the others had to keep their distance.

The second important precaution the UX researchers took to ensure the purity of their results was to try to prevent any verbal interference that might affect how the farmers would arrange the cards on the blanket. As they had planned it, only the UX researcher who moderated the card sorting session, the farmer, and, if necessary, the interpreter, were to speak during the sessions, and only to a minimal extent. To enforce this, UX1 and UX2 regularly reminded those present of this rule. As an example, sometimes it happened that one of the attendees who did not belong to the UX researchers asked one of the Marathi native speakers what was currently being debated on the blanket. In these cases, it was usually the case that one of the UX researchers reminded the speakers to please be quiet while the farmer sorted the cards. Besides that, it also happened that the UX researchers corrected their behavior among themselves. For example, it occurred that a farmer sorted rather hesitantly, whereupon the moderating UX researcher remedied the situation with a few explanatory words. In such situations, it regularly happened that one of the other UX researchers who was not sitting on the blanket called the moderator to order with statements such as “let him choose” or “let him sort out on his own.”

After the end of the sorting, the participants were asked to give names to the clusters they had formed. Subsequently, the UX researchers photographed the final arrangements of the cards. Back in the office, they copied the photos of these named arrangements into an Excel spreadsheet, where each named cluster was translated into a column of the spreadsheet. This means that when a participant formed and named seven clusters of cards on the blanket, for example, the UX researchers translated them into a table of seven named columns, with the number of lines in each column being determined by the number of cards in the corresponding cluster.

In the PowerPoint presentation the UX researchers gave when they returned from India the overall findings of the card sorting sessions were synthesized in rather general terms. In total, the presentation contains three slides dedicated to the card sorting sessions. The first slide explains that “[f]armers sort the information they want to see in the app chronologically and sequentially.” The second slide states that “[b]ased on the headers they gave their clustering of cards, farmers categorize the information they want to see process-/stage-wise.” Finally, a third slide critically remarks that “[p]articipants had problems including abstract information related to app settings, user profiles and community posts in general.” Most importantly, neither the Excel spreadsheets nor the results presented on the PowerPoint slides addressed the differences between non-users and users that had been manifested in the field. Instead, non-users were treated the same as users.

To wrap it up, this subsection has argued that—very similar to the method of prototype testing before—the card sorting method allowed the UX researchers, despite partly drastic deviations between the farmers they had encountered in the field and FLORA’s dominant user presentation, to generate a user representation that was aligned with the startup’s dominant user representation. Again, this alignment proceeded through a merging or collectivizing of experiences with deviant users with other experiences with less deviant users that the product team had in the field.

Conclusion

This chapter explored how the agtech startup FLORA produces knowledge about users of PHYTØ in order to adapt the design of the app to their needs. For this purpose, two strands of literature were combined. On the one hand, and more prominently, debates of STS-informed sociologists and anthropologists concerned with designer-user interactions (Akrich, 1992, 1995; Mackay et al., 2000; Oudshoorn & Pinch, 2005; Woolgar, 1990). On the other hand, media studies debates on the multi-situatedness of apps (Dieter et al., 2019; Morris & Murray, 2018; Morris & Elkins, 2015). By pulling these two analytic foci together, the chapter has shown how FLORA's interaction with small-scale farmers—and peripherally pesticide retailers—hinges on the constant creation and reconciliation of "user representations" (Akrich, 1995), both at a distance and in the field. In terms of this reconciliation, it was found that within FLORA, a dominant user representation prevailed that portrayed PHYTØ users as a heavily growing group of farmers and pesticide retailers who recognize the practical benefits of the app and use it accordingly, and that user representations that deviated from this dominant representation were either aligned with it or neglected.

These findings make an important contribution to debates regarding the designer-user interface that were outlined at the beginning of the chapter. To begin with, although the general idea of the chapter draws a lot of inspiration from Woolgar's (1990) early account of user configuration, its findings are very much consistent with the critics of Woolgar's text (Mackay et al., 2000) in that the chapter repeatedly demonstrated the great influence PHYTØ's users have on the app's developers. This influence was probably most noticeable in this chapter in the turmoil that fluctuating "user activity" and fluctuating "user retention" have caused within the offices of the startup. Interestingly, however, the methods described in this chapter that involved farmers of flesh and blood, that is, "prototype testing" and "card sorting," seemed to have a less configurational effect on the FLORA team. In this respect, it seems most appropriate to interpret them as accounts of the limits of a two-sided configuration between designers and farmers in a contemporary agtech company. Another important consideration of Mackay et al. (ibid.) is that more analytical attention should be paid to the way in which designers are configured by their organizations. In this chapter, this form of configuration was most evident in the strong influence that FLORA's investors have on how the startup generates, evaluates, or presents representations of its users. Particularly characteristic of this was the analyzed podcast episode in which FLORA's CEO pitches what has been referred to as the startup's "dominant user representation" throughout the chapter.

Beyond that, and in a more explicit way, the chapter expands on Akrich's research on designer-user interactions (Akrich, 1992, 1995). Bluntly speaking, the chapter has attempted a contemporary interpretation of Akrich's concept of "user representation techniques" (1995), which accommodates the "multi-situatedness" (Dieter et al. 2019) of new digital products, such as in this case an app. Through this approach, the chapter has shown that the multi-situatedness of apps does lead to a multiplication of possible user representation techniques that the developers of these technologies can employ to gain an understanding of their users. In the case of this chapter, this was most evident in the numerous performance metrics which the startup generates remotely. However, as Akrich (ibid.) has already made clear, more user representations do not necessarily equate to a better or more workable understanding of users, since, if the representations are incompatible, they necessitate more reconciliation work. This reconciliation is accomplished through a variety of strategies. The chapter identified several such strategies in FLORA's work, such as the altering of metrics, the hiring of expert users, or the collectivization of experiences with deviating users—strategies through which FLORA maintains the dominant representation of a heavily growing user base of dedicated users.

General conclusion

In what follows, I would like to conclude the dissertation. To this end, I start with a synthesis of the argument chapter by chapter. In other words, the section briefly revisits the exploratory process through which PHYTØ was turned into an asset, the construction of PHYTØ's selective recognition of plant pathology, the delicate enactment of PHYTØ's expertise at a distance, and the work of generating a coherent representation of small-scale farmers as PHYTØ users. This is followed by a more detailed summary of the dissertation's contributions to the three major bodies of literature with which it has entered into dialogue. More specifically, it is shown that the dissertation findings are largely consistent with, or slightly complementary to, much of the social science and humanities literature on digital agriculture. Furthermore, it is shown that the dissertation, although widely compatible in its position, represents a clearer methodological and conceptual extension in relation to existing social science and humanities research on agtech and foodtech startups. Moreover, it is emphasized that the dissertation has taken an initial step toward an ethnographic understanding of agriculture apps, but that there is still much space to further explore this phenomenon. Following this summary of the dissertation's contributions to specific strands of literature, some more transversal conclusions are drawn regarding what the dissertation calls the "appeal of little devices." After that, the conclusion ends with a description of aspects that could not be addressed within the scope of this work and a derived outlook on future research avenues.

Synthesis of the argument

In this dissertation, I asked how exactly the agriculture app PHYTØ—in keeping with a frequently reiterated claim of its developers—"feeds the world." In more formal terms, drawing on an STS-informed understanding of food security as a highly malleable and therefore controversial concept (De Raymond & Goulet, 2020), the dissertation asked how the problem of food security has been addressed by the agtech startup FLORA throughout the development of the agriculture app PHYTØ. The theoretical motive behind this question was to take the statement "PHYTØ feeds the world" seriously (cf., Latour, 2004). In practical terms this meant that the dissertation has made an effort not to blindly accept the statement, nor to immediately reject it in a preemptive critical reflex, but to zoom in on it while trying to decipher what "feeding the world" means for the developers of PHYTØ. The dissertation has answered this question with four arguments that revolve around four problems that have emerged in FLORA's efforts of breaking down the "grand challenge" (Kaldewey, 2018) of food security into a set of smaller problems (including the ones I describe) that can be solved by means of an app. These problems are turning the app into an asset, getting it to algorithmically recognize plant damages, upholding its claimed expert status at a distance, and creating a coherent representation of its users.

The first chapter argued that FLORA turned the agriculture app PHYTØ into an "asset" (Birch & Muniesa, 2020) by engaging in a process of "exploration" (Doganova, 2013) guided predominantly by the interests of venture capitalists. The chapter suggested the name "exploratory assetization" for this process. More simply put, the chapter showed that rather than knowing up front how to turn PHYTØ into an object from which continuous revenue streams could be extracted, the startup figured out how to do this only over time in interaction with the different worlds the app came into contact with. As the chapter showed further, this process implied continuous, sometimes drastic, changes in PHYTØ. In terms of the overarching research question of the dissertation, it can be said that these changes went hand in hand with a change in FLORA's approach to food security. This change was most pronounced in PHYTØ's gradually changing relationship to chemical pesticides: At first, the startup focused more on non-chemical, non-commercial alternatives to chemical pesticides (e.g., garlic tea, horsetail broth, nettle slurry), moving more within an alternative discourse on how to achieve food security. Later on, as funding rounds progressed, the startup became an advocate of a moderate, regulated, and responsible use of chemical pesticides, thus aligning itself with a more conventional discourse on how to achieve food security as maintained by the agrochemical industry and leading international organizations (e.g., FAO, CGIAR, WTO). Interestingly, and this may be the key message of the chapter, this change was not necessarily the result of a process in which the developers selected from a range of monetization options the one that most closely matched their convictions about food security; on the contrary, it was the result of a lack of viable monetization options other than pesticide sales. In this respect, the development of PHYTØ can be summarized as an exploratory assetization process with very limited destinations.

The second chapter argued that the work that is required to make the algorithms deployed in PHYTØ automatically classify plant damages gradually inscribes a selective recognition of the phenomenon of plant pathology into the app. More specifically, the chapter has examined the different "layers of knowledge production" (Bechmann & Bowker, 2019) that constitute the construction of PHYTØ's algorithms and shown how the phenomenon of plant pathology is subjected to different practices of "selection" (Lynch, 1990) at each of them. As the chapter has shown, the result of this process is twofold. On the one hand, this process enables PHYTØ to detect a relatively large number of plant damages (at the time of writing 500) on a relatively large number of crops (at the time of writing 30) with relatively high accuracy (higher than many human plant pathology specialists). On the other hand, this process is inevitably associated with excluding other aspects of the phenomenon of plant pathology from recognition. In an attempt to identify a pattern in these unrecognized aspects, the chapter has spoken of the "in-betweens" of plant pathology (e.g., differences between crop varieties, multiple plant damages in one leaf, severity of plant damages on leaves, or spread of plant damages in the field). To draw a bridge to the problem of food security, the chapter concluded that PHYTØ's selective recognition of plant pathology appears to be conducive to more pesticide-based ways of farming. This is because the non-produced knowledge about the aforementioned in-betweens is more important for less pesticide-based approaches to agriculture (e.g., IPM, agroecology, organic farming) than for other, more pesticide-based approaches. Having stated this conclusion, one thing must be clearly emphasized. This chapter does not claim that developers intentionally built a bias in favor of pesticide use into their algorithms for dishonest motives, as is often argued in popular science critiques of algorithms. Rather, the chapter has shown that PHYTØ's increased compatibility with more pesticide-based ways of farming—a compatibility that could be labeled as bias—gradually finds its way into the technology through a combination of mundane design decisions, technical prescriptions, and economic constraints.

The third chapter argued that maintaining PHYTØ's claimed expert status at a distance requires the developers of the app to constantly align their vision of adequate mobile extension with that of their users for fear of losing these users as recipients of the app's expert advice. At the start of the chapter, it was shown that the idea of providing agricultural extension services via mobile technologies is rapidly gaining popularity (Fabregas et al., 2019), but that from an anthropological perspective the workings of these technologies are poorly understood (Stone, 2011). Building on this, the chapter has argued that the success or failure of mobile extension apps in circulating knowledge should be viewed as the result of a successful or unsuccessful "enactment" (Carr, 2010) of expertise. In the case of PHYTØ, this enactment turned out to be successful, at least during the period studied. The reason for this successful enactment was that FLORA radically changed PHYTØ's concept of mobile extension as a function of user behavior: In what I called the "early phase," FLORA focused on presenting PHYTØ users with lengthy text-based advice that included relatively narrow instructions on how to farm.

However, FLORA found that users did not really read this advice. Put differently, PHYTØ's enactment of expertise was in jeopardy. This led to what I call the "late phase" of PHYTØ's mobile extension services, in which FLORA focused on presenting users with a curated selection of short pesticide recommendations (both biological and chemical), while leaving the final choice up to the user—a less narrow way of giving instructions on how to farm. This conception of mobile extension found more appeal among users. Put differently, this conception of mobile extension maintained PHYTØ's enactment of expertise. To relate these results to the overall research question, on the level of providing mobile extension services too we can thus notice a shift towards a more productivist understanding of "how to feed the world" manifested in the increasingly central role of pesticides in the app's advice. In this case, the shift was almost exclusively driven by the fear that users might stop using the app. Following up on Henke's (2008) argument that in-person extension is a "fundamentally conservative technique of social change" (p. 146), the chapter concluded that there is much to suggest that mobile extension efforts will be even more conservative, as the ties between farmers and extension apps appear to be far more fragile than the ties between farmers and most in-person extension agents.

Chapter four argued that in order to gain an understanding of its users, FLORA continuously generates "user representations" (Akrich, 1995) by employing different "user representation techniques" (ibid.) that operate both at a distance and in the field—a circumstance that is facilitated through the "multi-situatedness" (Dieter et al., 2019) of apps. More specifically, the chapter has argued that within FLORA a dominant user representation prevails that portrays PHYTØ or MERCHANT users as a growing group of farmers or pesticide retailers who recognize the practical benefits of the apps and use them accordingly. Still following Akrich, the chapter went on to demonstrate that the user representation techniques that FLORA employs sometimes yield user representations that deviate from this dominant user representation. In this case, the FLORA team must find strategies to reconcile the divergent user representations with the dominant user representation to obtain a coherent user representation capable of ensuring that the work on PHYTØ continues. These strategies included the adjustment of performance metrics, the hiring of expert users, or the collectivization of experiences made with deviating users in the field. Furthermore, following Mackay et al. (2000), the chapter argued that the case of FLORA should not only be interpreted as a case in which designers and users configure one another but also as a case in which designers are configured by their organization. In the case of this chapter, the configuring organization was the organizational form of the startup and its accompanying figure of the venture capitalist. More specifically, this type of configuration became tangible through the strong influence of FLORA's investors on the way the startup generates, evaluates, or presents representations of its users. In terms of the overarching question of the dissertation, the findings of this chapter suggest that in the pursuit of food security with digital technologies, the semi-fictional character of the user will increasingly conflict with the less fictional character of the small-scale farmer.

Digital agriculture, food security, and PHYTØ: Perpetuation of productivism

In many ways, the findings of the case study of PHYTØ align with and extend the existing literature on digital agriculture and its potential contribution to achieving the goal of food security. More specifically, this means that there is much to suggest that digital agricultural technologies like PHYTØ perpetuate or reinforce productivist forms of agriculture, while intentionally or not marginalizing alternative ways of thinking about and working toward the goal of food security.

First, this was evident in PHYTØ's relationship with the agrochemical industry. More specifically, the findings of this dissertation are congruent with the widely held argument of critics of the political economy of digital agriculture that most digital agriculture technologies strengthen the oligopolistic market positions of dominant corporations in the agricultural sector, particularly agrochemical corporations (Prause et al., 2021; Rotz et al., 2019; Wolf & Buttel, 1996; Wolf & Wood, 1997). Beyond that, the thesis refined this argument by showing that this strengthening can occur in multiple ways at once. In the case of PHYTØ, it occurred in two ways. On the one hand, largely invisibly, by renting out access to a selection of PHYTØ's image recognition algorithms in a white-labeled fashion to agrochemical companies, who then use them in company-branded apps to increase the sales of their core products. On the other hand, more visibly, by PHYTØ itself serving as a platform to broker additional sales of pesticides and other inputs to these companies.

Second, PHYTØ's perpetuation or reinforcement of productivist forms of agriculture was observable in the app's relationship to data. In this respect, too, the case of PHYTØ strongly coincides with the existing social science and humanities literature on the subject. As a first example, it coincides with Bronson and Knezevic's (2016) argument that big data-driven technologies perpetuate, rather than break, historical patterns of inequality between farmers and producers of pesticides and other inputs. In the case of PHYTØ this is reflected, for instance, in the fact that FLORA allows agrochemical companies to produce meta-knowledge about farmers, while farmers are only allowed to query knowledge about agricultural practices. Beyond that, the findings of the thesis resonate with and expand on what Carbonell (2016) calls "the selective use of big data in industrial agriculture" (p. 3), by which she means that the use of big data on conventional farms focuses "almost exclusively on inputs and production" (ibid.), while other aspects regarding which big data could be produced and analyzed, such as "externalities" or "vulnerabilities" of the farms, are neglected. The dissertation has shown that this argument also applies to the use of big data on small non-industrial farms. This was particularly visible in the second chapter, where I described how a bias in favor of pesticides was gradually inscribed into the diagnostic feature of PHYTØ—an argument that equally resonates with Carolan's (2020) argument that agricultural algorithms lead to various types of lock-ins including technological lock-ins.

Third, PHYTØ can be seen as perpetuating or reinforcing a tendency in productivist forms of agriculture in which companies from countries of the Global North predominantly view farmers in countries of the Global South as a population from which to extract additional revenue. In this sense, the thesis resonates, in part, with Fraser's (2019) argument that providers of digital agricultural technologies are engaging in processes of "data grabbing." More specifically, the dissertation shares Fraser's concern about the fact that companies in the Global North are accumulating ever larger amounts of data on farmers from countries in the Global South, while arguing for a different understanding of how this accumulation occurs. As the thesis has shown, in the case of FLORA it does not seem appropriate to speak of "data grabbing," since the term "grabbing" implies that the data that is being accumulated already exists and just passively waits to be harvested. The dissertation, on the other hand, has argued that the accumulation of data by providers of digital agriculture technologies occurs through a collective construction process in coordination with strategic goals (e.g., expansion into a new region with other crops)—a process that bears much resemblance to the construction of "raw data" described by Denis and Goëta (2017). At the same time, the dissertation echoes Fairbairn and Kish's (2021) argument that the efforts of providers of digital agriculture technologies in countries of the Global South are usually underpinned by the narrative of a knowledge deficit, or as they call it, a "data deficit," on the part of the respective farmers that does not do justice to the competencies of these farmers and ignores the historical drivers of their increased vulnerability (e.g., colonialism, capitalism, neoliberalism).

Agtech, food security, and PHYTØ: From solutionism to exploration

On a more specific analytical level, the case study of PHYTØ has reaffirmed and refined social science and humanities debates about how agtech (and foodtech) startups address agriculture-related "grand challenges" (Kaldewey, 2018) including food insecurity. More specifically, the dissertation proposed to go beyond the critique of technological solutionism that is often leveled at these startups and approach them, in addition, as "spaces of knowledge production" (Fochler, 2016). Building on this, this subsection concludes by outlining how this proposition relates to the argument that the trajectory of agtech startups ought to be seen as a process of "exploration" (Doganova, 2013).

To begin with, the thesis offers a methodological extension to pre-existing social science and humanities debates on agtech and foodtech startups. This is because most existing studies examine several such startups in one go. In contrast, the present case study is, I believe, one of the first multi-sited ethnographic case studies of a single such startup over an extended period of time. As might be expected, such a focus on a single agtech startup has given the project more analytical depth with respect to the everyday work practices that constitute the corresponding innovation process, which sheds a slightly different light on some of the theoretical debates surrounding agtech and foodtech startups that have been going on so far.

Most importantly, the dissertation complicates the widely held argument among social science and humanities scholars studying agtech and foodtech startups (e.g., Fairbairn & Guthman, 2020; Guthman et al., 2022; Reisman, 2021) that these startups are first and foremost a manifestation of "technological solutionism" (Morozov, 2013). Morozov provides two cognate explanations of the term technological solutionism that differ in their degree of criticism. First, he describes it as the reduction of complex problems to rather simplistic problem definitions as a function of the technological means available to a given tech company. Second, building on this, he further specifies the term by stating that "what many solutionists presume to be 'problems' in need of solving are not problems at all" (p. 6). This thesis concurs with this critique up to a point but is reluctant to reduce FLORA's activity to the notion of technological solutionism. More specifically, the thesis joins the critique that in the case of FLORA, one can observe a reduction of the complex problem of food insecurity into simpler problems that are solvable with the technologies available to the startup. However, the dissertation adds a layer of complexity to this critique. This is due to the fact that it has shown that technologies are not a fixed variable in this process of reduction, but that they are in constant progression, and that they change in response to the problems that they are designed to solve. Doganova's (2013) notion of "exploration" conveys this idea very clearly—an idea that can be traced back to early ANT-informed studies of innovation. A characteristic example of such a study is Latour's analysis of an innovation process based on mapping its "technogram" and its "sociogram" (Latour, 1987), that is, the development of the non-human and the human actors involved in the process over time. Given this approach, one could say that the present dissertation added a third to these two analytical axes that might be labeled the "problemo-gram"— an axis that maps the various problems that a technology raises for its developers during its development process. It is equally in this sensitivity to the changing nature of problems where the conflict of the dissertation with Morozov's second explanation of technological solutionism lies. To put it clearly, I would never go so far as to claim that the problems that the actors of FLORA are dealing with on a daily basis "are not problems at all," suggesting that the actors are subject to some sort of delusion, ideological or otherwise. On the contrary, the thesis is based on the pragmatist view that taking the problems of the actors in the emerging agtech and foodtech sectors seriously might be the only way to understand this latest iteration of agricultural techno-capitalism.

On that note, the thesis suggested that a productive way of taking the problems of the actors involved in the emerging agtech and foodtech sector seriously is to regard the respective startups as "spaces of knowledge production" as proposed by Fochler (2016) with respect to biotechnology startups. As such, the dissertation seeks to build a bridge between the very promising emerging body of STS-informed research on agtech and foodtech startups and the existing, somewhat scattered STS-informed research on biotechnology startups (e.g., Rabinow, 1997; Smith-Doerr, 2005). To draw a preliminary comparison, unlike the biotech startup-affiliated scientists that Fochler (2016) interviewed for his study, only few of my informants at FLORA had longstanding backgrounds in academia. Accordingly, FLORA was hardly characterized in my data as an alternative space for knowledge production compared to universities. Instead, the actors of FLORA compared themselves more to providers of in-person agricultural extension services and saw themselves as a link between agricultural science, industry, and farmers. In this sense, the proliferation of agtech startups could also be interpreted as a continuation of the process described by Jas (2005) of introducing the figure of the agronomist and science-based methods into agriculture. In other words, the case of FLORA raises the question of what happens to agricultural sciences and agricultural practices when startups increasingly introduce themselves into these realms as new knowledge-producing actors (similar to the way biotechnology startups have begun to introduce themselves into the life sciences before). Based on tentative comparisons like this, I hope to have shown that taking agtech startups seriously as spaces of knowledge production can lead not only to a deepening of research on the sector itself, but also to potentially fruitful comparisons with related sectors in which startups matter.

This attentiveness to knowledge is equally central to this dissertation's view that agtech startups should first and foremost be understood as being in a process of "exploration" (Doganova, 2013). The reason for this is that startups need to continuously produce knowledge about the world they interact with in order to potentially adapt their actions. This manifested itself very clearly in the case of FLORA in the large number of devices that the startup generated and that were put to the test by the actors with whom it interacted (e.g., algorithms, business plans, pitch decks, prototypes, cards, text-based advice, pesticide recommendations, etc.), as a result of which the trajectory of the startup and the app were altered or not. All of the above devices are thus to be considered, among other things, devices for knowledge production. Through this expandable collective of devices, these organizations take on an increasingly important tactile or sensory function in agricultural markets of the early 21st century, helping hitherto mainly dominant actors within these markets (e.g., Big Ag, governments, investors) to substantiate their notions of how to feed the world with digitally-enhanced knowledge claims. In short, although PHYTØ breaks down the complex problem of food security into a list of smaller, more manageable problems, the way in which the app contributes to the pursuit of food security cannot be reduced to a gesture of reduction.

Agriculture apps, food security, and PHYTØ: The fragility of mobile extension

Ultimately, the dissertation aimed to provide the impetus for an increased ethnographic examination of agriculture apps. More specifically, it was shown that existing research on agriculture apps is dominated by economists. These studies are usually concerned with studying the effectiveness of agriculture apps in increasing farmers' productivity through "knowledge transfer," with the dominant methodology being randomized controlled trials (e.g., Cole & Fernando, 2012, 2020). A common argument among this group of researchers is that agricultural apps have a high potential for mediating robust knowledge from science to farmers, and that only isolated "market failures" can jeopardize this potential including the associated productivity gains (Fabregas et al., 2019). This dissertation questioned this assumption by paying greater attention to the everyday practices through which the intended knowledge mediation of such apps may occur or not, and showed that the success or failure of such operations primarily depends on a collective “enactment” (Carr, 2010) of agricultural expertise.

To put it a little more in detail, the dissertation has shown that leading development economists—in line with telecommunications companies, agrochemical companies, politicians, and international agricultural organizations—tend to argue that agriculture apps have great potential to provide science-based agricultural knowledge to small-scale farmers in a cost-effective manner, and thus increase their productivity in times of a weakening in-person extension sector and rapidly changing economic and environmental conditions (Fabregas et al., 2019). However, the dissertation also made clear that beyond these grand assertions, development scholars are quite reflexive that mobile phone-based extension services do not always meet the high expectations placed upon them (Baumüller, 2017). The study by Fabregas et al. (2019) cited above attributes the reasons for why agriculture apps may not provide knowledge that is useful to farmers to a variety of potential “market failures.” If we think back, as examples of such market failures they cite situations where farmers may not want to pay for information from private providers, companies may intentionally offer “biased” information to increase input sales, or public institutions may offer overly technical or uninteresting information. The dissertation contended that these descriptions of so-called market failures are helpful in getting an initial idea of the problems that agriculture apps may cause in practice. However, it also contended that the relevant studies generally paint a simplifying picture of knowledge mediation through agriculture apps, in that they usually portray knowledge mediation as a relatively unproblematic, one-way process from academia to farmers, provided that some external conditions associated with “the market” are met.

To circumvent such a simplistic account of knowledge mediation through agriculture apps, the dissertation took a step toward an STS-informed ethnographic examination of these technologies and their involvement in the pursuit of food security. In the absence of other analogous references, Stone’s (2011) anthropological analysis of a provider of mobile extension services based on older ICTs was a particularly important inspiration in this endeavor. As he has shown, when providing mobile extension services, the scientific robustness of the mediated knowledge is only one side of the coin. More importantly, however, he showed that it is important for the providers of the respective services to enter into mutual interaction with the farmers who are to benefit from the services, in order to adapt the type of knowledge offered to their everyday problems. Otherwise, providers would run the risk that farmers might not accept the knowledge offered to them as expert advice. In short, Stone’s study has shown that the mediation of knowledge through mobile extension services is more problematic and less one-way than is often claimed by development economists and other proponents of such services. Building on this, the dissertation argued that the success or failure of knowledge mediation via agriculture apps should be regarded as the result of a collective "enactment" (Carr, 2010) of agricultural expertise at a distance, that is, not as something inherent to the respective technologies or their developers, but as something that is continuously done and redone in a back and forth between the objects, producers, and consumers of knowledge that a given act of knowledge mediation involves. Simply put, the dissertation has shown that the mediation of knowledge through agriculture app is a more complex endeavor than assumed in most of the literature on the matter—which presents many points of departure for STS-informed ethnographic analyses concerned with it.

The appeal of little agriculture devices

One of the sub-questions of the dissertation was whether little devices like PHYTØ could be seen as a response to ongoing criticism of large-scale agricultural modernization projects of the past, such as the "green revolution." This question was inspired by Collier et al.'s (2017) argument that "little development devices" should be seen as responses to ongoing criticisms of controversial large-scale development modernization projects of the past. After bringing this case study to a close, I think it is appropriate to draw an analogy between "little development devices" and PHYTØ. In other words, I think it is advisable to think of PHYTØ as a "little agriculture device" that constitutes a response to the ongoing criticism of large-scale agricultural modernization efforts of the past. This raises the question of how this response can be put into words, to which three answers can be given at this point.

First, agriculture apps respond to controversies related to agricultural modernization projects of the past by attempting to combine the promise of scalability with the promise of customizability. While the idea of scalability has shaped agriculture since the days of colonial plantations (cf., Mintz, 1986; Tsing, 2012), and reached an unprecedented popularity with the technologies developed in the wake of the "green revolution" (Fitzgerald, 1986), the idea of combining scalability with customizability seems to be intimately tied to digital agriculture technologies and the associated promise that the respective technologies will persuade farmers to use exactly the right amount of inputs for their individual situations. Agriculture apps appear as the epitome of this trend. On the one hand, smartphones are spreading rapidly among farmers in certain countries of the Global South, which immediately imbues agricultural apps with the nimbus of great scalability. On the other hand, considering that apps create a digital connection between designers and users (e.g., performance metrics), and that the software design of an app is more immediately malleable than, say, the material shell of a tractor, the claim that the providers of agriculture apps can adapt these technologies to the individualities of their users seems almost intuitive. In observing the day-to-day development practices of PHYTØ, however, it became clear that there is a tension between upscaling and customizing—an observation that can probably be extended to other agriculture apps. A first illustrative example where this tension became clear is FLORA's failed attempt to implement the PLANT PRO feature, with which PHYTØ's developers originally intended to provide "customized" advice to users, but quickly realized that this task would require too much work given the size and heterogeneity of their user base. As one of the co-founders put it, the feature "did not scale." Similarly, this tension played a role in PHYTØ's shift from longer text-based advice to concise pesticide recommendations, in that the standardized nature of pesticides makes the latter easier to maintain and scale up. A last illustrative example in which this tension manifested itself is FLORA's strategy of prioritizing crops and plant damages for which to develop new image recognition algorithms. In this case rather than striving for completeness or at least breadth (increasing customizability), the startup created a selection of crops and plant damages that it hoped would cover the greatest number of user problems relative to the resources required to develop the corresponding algorithms (increasing scalability). In summary, the developers of PHYTØ seem to actually strive to combine scalability and customizability, in order to avoid some of the mistakes made in agricultural modernization projects of the past (e.g., ignoring local agricultural conditions), yet when it comes to a conflict between scaling up and customizing, they still opt for scaling up rather than customizing—which seems to explain the continued productivist tendency of the project.

Second, agriculture apps respond to controversies tied to agricultural modernization efforts of the past by creating a mundane interface between farmers and agrochemical companies. If we think back to Morris and Elkins (2015), one of their main arguments was that the main difference between apps and other software commodities is their "mundaneness" by which they mean that more and more everyday activities are performed with apps and that apps are increasingly insinuating themselves into routines and habits of everyday life. This argument seems to explain the great interest of companies that traditionally tried to modernize agriculture by making farmers use additional pesticides and other inputs that they produce. For these companies, technologies like PHYTØ represent an additional interface with consumers that, if all goes smoothly, will nestle into the everyday lives of farmers without the companies themselves having to approach them. In other words, one could say that by marketing pesticides and other inputs through PHYTØ, the respective companies are less likely to face public headwinds because the app exposes them less to public discourse than, say, a company-led marketing campaign. Moreover, the app's instant diagnoses wrap its product recommendations in a cloak of facticity, making it nearly impossible for an outsider who is not a specialist to question them. It can thus be noted that, from a corporate perspective, agriculture apps appear to be a reaction to controversies surrounding agricultural modernization projects of the past in two ways. On the one hand, by providing a more mundane interface for companies to sell pesticides and other inputs to farmers. On the other hand, by reducing companies' exposure to potential controversy by allowing agriculture apps speak for themselves.

Third—rather a supplement to the above response than an independent response—agriculture apps respond to controversies related to agricultural modernization efforts of the past by getting Big Tech involved in the alleged pursuit of food security. As pointed out by Bronson and Sengers (2022) Big Ag companies are increasingly looking at Big Tech companies and the data-driven products and services they offer as a way to give their operations a cleaner image. As they describe it, Big Ag corporations increasingly attempt to change their image away from classical producers of seeds, chemicals, or heavy machinery and towards "data corporations" in the image of Silicon Valley giants. As demonstrated in this dissertation, agricultural apps are an effective mediator for this marriage of Big Ag technologies (e.g., pesticides, seeds, fertilizers) and Big Tech technologies (e.g., algorithms, web analytics services, cloud storage)—an observation that is not exclusive to agriculture apps but applies to many digital agriculture technologies.

Aspects not covered, and avenues for future research

Needless to say, this dissertation has emphasized certain aspects of PHYTØ's pursuit of food security and neglected others. Some of these neglected aspects were clear from the outset, as a result of the research design of the dissertation. Others emerged as the dissertation evolved. This final subsection will highlight some of the aspects that have fallen short in my research project in order to derive recommendations for future research.

A first problem that the dissertation could have addressed in more detail are the material effects of PHYTØ on plants and other lifeforms that the app touches (fungi, viruses, insects, etc.). Indeed, inspired by Tsing's (2015) seminal analysis of the trajectory of the Matsutake mushroom, an early idea for the dissertation was to produce a case study that would give equal analytical weight to the materialities that constitute digital agricultural technologies and the lifeforms that these technologies touch upon in the field. In the end, a dissertation emerged that places more emphasis on the materialities that constitute digital agriculture technologies and only peripherally touches on the multi-species encounters that constitute agricultural practice in the field. There are three reasons for that. First, I took very seriously the methodological premise of taking seriously the problems of the actors that make up the case of PHYTØ—which I interpreted as the core team of FLORA. Quite frankly, these actors were more concerned with algorithms, pictures, and user numbers than with roots, crop rotations, or the soil microbiome, which translated into my data. This tendency could have been cushioned, I believe, had I had the opportunity to interact more and over an extended period of time with farmers who use PHYTØ, which was not possible with the resources at my disposal, as PHYTØ users are widely distributed across India and, in most cases, I do not speak their language. In short, I think it would be very fruitful to see more research projects that seek to look ethnographically and in a symmetrical fashion at the materiality of digital agricultural technologies and their material effects on the lived environment, wherein, from my point of view, an important difficulty to consider lies in achieving unrestricted field access to the two worlds outlined. As an addendum, this call for further ethnographic research can also be related to the nexus of the materiality of digital agriculture technologies and the material consequences of pesticides and other inputs in the field as they are shaped by digital agriculture technologies, which is also hardly researched in depth so far.

A second important problem that the dissertation implicitly touched on but did not theoretically delve into is the production of "ignorance" (Gross & McGoey, 2015) or "non-knowledge" (Gross, 2007) through digital agriculture technologies. To give an example, what has been called in this dissertation the "selective recognition" of PHYTØ's automatic image recognition could equally be theorized as a problem of producing ignorance (e.g., concerning less pesticide-oriented approaches to plant pathology). This theoretical framing does not belittle the accuracy of the majority of PHYTØ's diagnoses. Rather, it suggests that as a result of PHYTØ's generation of knowledge about some aspects of plant pathology and not others, there is a shift in the ratio of knowledge and non-knowledge circulating in society in favor of a particular (pesticide-oriented) agricultural paradigm. Kleinman and Suryanarayanan (2013, 2015), for example, have written extensively about the intentional production of ignorance by the agrochemical company Bayer in the controversy over the sudden and massive dying of entire bee colonies as of 2005 known as the "Colony Collapse Disorder" (CCD). With respect to the case of PHYTØ, I would not go so far as to speak of an intentional production of ignorance, as Kleinman and Suryanarayanan do in their argument on said controversy. Rather, I would suggest that we see ourselves confronted with an unintentional production of ignorance that gradually inscribes itself into the technology and—to stress this again—does not deny that PHYTØ simultaneously generates robust knowledge (e.g., accurate diagnoses). To wrap things up, I think another productive avenue for future social science and humanities research on digital agricultural technologies is to ask how these technologies unintentionally generate non-knowledge about particular agricultural objects, and thus change the ratio of agricultural knowledge and non-knowledge circulating in contemporary agrifood systems.

A final, less theoretical, suggestion for future research is that it seems important to think more about what might be titled "national agtech and foodtech cultures." As evidenced by the references mobilized in this dissertation, most of the cutting-edge social science and humanities research on agtech and foodtech startups to date has focused on the United States or Silicon Valley specifically. However, as Fochler (2016) has pointed out, with reference to Rabinow (1997), there are significant national differences in how innovation and knowledge are generated in biotechnology startups, for example, due to differences in the availability of public funding or venture capital in certain countries. It is safe to assume that this argument can be applied to agtech and foodtech, which opens up a new analytical task of examining how exactly these national differences manifest themselves in agtech and foodtech startups in countries including, but especially other than, the United States. This dissertation has focused on a German agtech startup with regional offices in India. Although the dissertation certainly conveyed some of the culture within this transnational startup, the more comparative question of a national agtech and food tech culture or national agtech and food tech cultures, in the plural, was not at the forefront. Likewise, this project has given a taste of the numerous agtech projects currently springing up in India and other countries in Asia and Africa though it has not explored the possibilities of the project of "provincializing" (Law & Lin, 2017) STS-informed research on agtech and foodtech to its fullest.

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RÉSUMÉ

Face aux nombreuses crises auxquelles l'agriculture est confrontée aujourd'hui (p. ex., changement climatique, perte de biodiversité, insécurité alimentaire), un nombre croissant d'entreprises privées développent des technologies numériques comme solutions potentielles, dont les applications mobiles jouissent d'une popularité particulière. S'appuyant sur les études des sciences et des techniques, la sociologie économique et la sociologie agricole, cette thèse examine l'essor des applications agricoles et ce qu'il révèle sur la façon dont le secteur technologique aborde les problèmes liés à l'agriculture. La thèse entreprend une étude de cas ethnographique de PHYTØ, une application dont le développeur, une startup agtech appelée FLORA, déclare qu'elle contribuera à « nourrir le monde » en aidant les petits agriculteurs à diagnostiquer et à traiter les dommages aux plantes. Empiriquement, la thèse reconstruit la trajectoire de PHYTØ sur une période de neuf ans (2014-2022) et montre comment la réponse de l'appli à la pathologie végétale, et par extension à la sécurité alimentaire, a changé au fil du temps. Elle est divisée en quatre chapitres qui tournent autour de quatre problématiques caractérisant le travail quotidien de la startup, à savoir l'assetization de l'agtech, la construction d'algorithmes, la performance de l'expertise et la représentation des utilisateurs. Dans l'ensemble, les résultats de la thèse confirment l'argument largement accepté parmi les chercheurs en sciences sociales et humaines selon lequel les technologies de l'agriculture numérique ont tendance à renforcer plutôt qu'à résoudre les problèmes agricoles enracinés dans le passé (p. ex., la surutilisation des intrants). En même temps, la thèse approfondit cette littérature en montrant comment ce renforcement émerge dans les pratiques de travail quotidiennes par une interaction de décisions de design ordinaires, de pressions économiques, de contraintes technologiques et des résistances matérielles des matières agricoles.

MOTS CLÉS

agriculture numérique, sécurité alimentaire, agtech, applis, assetization, algorithmes, expertise

ABSTRACT

In light of the many crises facing agriculture today (e.g., climate change, biodiversity loss, food insecurity), an increasing number of private companies are developing digital technologies as putative solutions, with mobile apps enjoying particular popularity. Drawing on science and technology studies, economic sociology, and agricultural sociology, this dissertation examines the rise of agriculture apps and what it says about how the tech sector addresses agriculture-related problems. The thesis undertakes an ethnographic case study of PHYTØ, an app whose developer, an agtech startup called FLORA, claims it will help "feed the world" by assisting small-scale farmers in diagnosing and treating plant damages. Empirically, the thesis reconstructs the trajectory of PHYTØ over a nine-year period (2014-2022) and shows how the app's response to plant pathology, and by extension food security, has changed over time. It is divided into four chapters that revolve around four problems characterizing the everyday work of the startup, namely assetizing agtech, constructing algorithms, enacting expertise, and representing users. Overall, the findings of the thesis confirm the widely accepted argument among social science and humanities scholars that digital agriculture technologies have a tendency to reinforce rather than solve agricultural problems rooted in the past (e.g., input overuse). At the same time, the thesis expands on this literature by showing how this reinforcement emerges in everyday work practices through an interplay of mundane design decisions, economic pressures, technological demands, and material resistances of agricultural matters.

KEYWORDS

digital agriculture, food security, agtech, apps, assetization, algorithms, expertise