DATA FARM: PRECISION AGRICULTURE AND THE GOVERNMENT OF NATURE

Christopher J. Miles

Submitted to the faculty of the University Graduate School
in partial fulfillment of the requirements
for the degree
Doctor of Philosophy
in the
Department of Communication & Culture
and the
Luddy School of Informatics, Computing, and Engineering
Indiana University
December, 2021

Accepted by the Graduate Faculty, Indiana University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Doctoral Committee

Eden Medina, PhD

Theodore Striphas, PhD

Stephanie DeBoer, PhD

Nathan Ensmenger, PhD

Rebecca Lave, PhD

Selma Šabanović, PhD

Date of Defense, December 9th 2021

For you, Mom

ACKNOWLEDGEMENTS

Honestly you're all responsible, and I won't forget it. But some of you own a fuller share of the credit [blame], and I wouldn't want to rob you of any warranted respects or recognitions. By no means, of course, do I feel able to name or sufficiently convey the gratitude and friendship I feel for those I thank here for their help in this process, and it goes without saying that this list is an unjustly incomplete ledger of those to whom I owe my gratitude.

First, I must express my gratitude to the members of my doctoral committee, including my *de facto* chairs Drs. Eden Medina and Ted Striphas, my *de jure* advisors Drs. Stephanie DeBoer and Nathan Ensmenger, and my committee readers Drs. Rebecca Lave and Selma Šabanović. As members of this moot each one of you, in your own ways, have shown me true generosity and support in the face of an unusual and labyrinthine process, something for which I am and will remain especially indebted and thankful to you. Similarly, I would like to single out past members of my committee Dr. Jon Simons and Dr. Elizabeth Ellcessor for their friendship, support, and encouragement throughout this process.

I want to thank the outstanding collaborators I've enjoyed working with on projects related to this one. These include Dr. Nancy Smith, Dr. Zenia Kish, Dr. Ben Peters, Dr. Thomas Patrick Pringle, and Rian Wainstreet, as well as Drs. Francis Lee, Lotta Björklund Larsen, and Evelyn Ruppert. I want to acknowledge Dr. Steven Wolf for his generosity and for the deadline, as well as thank and/or accuse Drs. Bennett Schaber, Amy Shore, Thomas Judd, and Geraldine Forbes for your early and significant influences. Above all, I am effusively grateful to my very dear friends Martin Law and Dr. Daniel Walker, for the extraordinary and outrageously generous support – professionally, intellectually, emotionally, and… uh, culturally? – they selflessly and repeatedly provided me over this long, arduous, and often despairing process. I can only hope to return the same in kind.

An infinite list of colleagues and friends have earned my real appreciation and affection, among them Katie Altizer, Angela Babb, Jesse Balzer, Alyssa Bossenger, Katreen Boustani, Megan Brown, Iris Bull, Beatrice Choi, Jacob Gaboury, Javon Goard, Jimmy Gilmore, Blake Hallinan, Tristan Gohring, Forrest Greenwood, Dan Hassoun, Boose Henricks, Jamie Hook, Emma Johnson, Katie Johnson, Keehnan Konya, Jessica Mann, Alex Mirowski, Paula Mate, Linde Murugan, Landon Palmer, JR, Steven Tsung-Han Sher, Nancy Smith, Andrea Sterling, Rosemary Steup, Alex Svensson, Jennifer Terrell, Dan Quarooni, and Eric Zobel. Finally, I would like to thank my friend and colleague Oscar Lemus for his endless generosity, cheer, and friendship; as well as for all the tea I stole from your desk this year. Thank you for that, and for everything else. There are so many more I could and should name here – if I failed to, forgive me, and yell at me next time I see you, I'll buy you a beer as weregild.

I would like to single out the staff of the Departments of Communication and Culture and Informatics – particularly Kathy Teige – for thanks, as well as the folks at the National Science Foundation and Indiana University College of Arts and Sciences for their votes of confidence in my scholarship with their support.

A special thank you is due to Wolves in the Throne Room, Cantiga, and Dungeon Synth as a genre for being there when and how I needed you. Thanks/curses to the makers of Heroes of Might and Magic III, Dominion Online, and The Witcher III; thanks as well to The Bishop, The Atlas, the Bloomington Bike Project, and Mother Hubbard's Cupboard. Endless gratitude to and solidarity with Gandalf, Radagast, Nedd Ludd, Captain Swing, birds, Beren Erchamion, *Pinus* *strobus*, the IU Graduate Workers Coalition, Black Lives Matter, and anti-fascists of every kind, every where.

To my very close and very old friends in Onondaga, Syracuse, the North Country, and otherwise scattered around the world, I owe you everything. Thank you for the love, happiness, and belonging you've given me, without which I wouldn't be writing this. The same is only more true and owed to my family – to Grandma Helen, Mom, Dad, Evan, Eric, Theresa, Campbell, and everyone else – thank you for everything and all of it. Finally, to Kassandra: you have supported, soothed, cared, fed, read, and loved me to this pass. Whatever I've managed to accomplish here is simply not my accomplishment alone: it's been with and due to you.

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This thesis presents a study of recent socio-technical changes in conventional agriculture that it argues represent the emergence of an informatic ideal in farming. Known as precision agriculture (PA), the integration of digital management, media, and surveillance technologies in farming is popularly presented as a revolutionary transformation. Proponents contend that digital media, biotechnology, computing, Big Data, and automation will help create a more efficient, transparent, productive, and environmentally friendly food system, staving off looming global famine and ecological ruin. This work argues to the contrary that PA represents not a revolution but an evolution, an intensification of the conventional capitalist agri-system responsible for the very social and environmental problems it is presented as solving.

While advocates of precision agriculture portray it as a radical, even epistemological break with the past, this dissertation locates contemporary developments in agricultural digitization in a deeper historical context of capitalist rationalization imperatives and the birth of modern governmentality. Drawing on extensive historical and discursive analysis as well as ethnographic research in the United States and Canada with farmers, researchers, government officials, and businesspeople, this work 1) advances an argument and framework for a media studies of agriculture; 2) describes the socio-technical system of PA, identifying it as part of a broader, emergent informatic ontology; 3) historicizes and critiques the ahistorical discourse of PA as "revolution," arguing PA is better understood as the introduction of an informatic ideal of control to farming, one which represents the intensification of an extant, industrial capitalist form, and 4) highlights the emerging significance of agricultural data in the pursuit of "transparency" and "traceability," elements of an imaginary in which PA implements a modern,

digital “police des grains,” part of broader efforts to govern and control nature in the name of sustaining the extant socio-economic order. Finally, it concludes with a brief outline of an alternative techno-political vision for digital control in agriculture, i.e. as an opportunity to foster new forms of social and ecological democracy and more equitable co-existence between and among human and non-human species alike.

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INTRODUCTION

I. "Our Intent is Pure"

In May of 2015, the *New York Times* published a story on American farmers flying drones illegally on their farms, at times openly daring state authorities to catch and punish them. The use of drones for domestic purposes did not become legal in the United States until 2016, so in guiding "unmanned aerial vehicles" over their fields in 2015, American farmers were explicitly and deliberately breaking the law. One such farmer interviewed in the piece, Jean Hediger, defended herself and fellow rebel growers, insisting "our intent is pure." "Without being able to fly drones over our fields," she explained, "they are asking us to remain in the dark ages" (Turkewitz 2015).

Out of a total 2.3 billion acres of land in the United States, 900 million of those are land in farms, roughly 38% of American territory (USDA NASS 2019).[1] On that land, US farmers produce more food, more intensively, with comparatively fewer people and less territory than other major agricultural states like India and China. Behind the achievements in farming that made such productive intensity possible stand hundreds of years of transformations in science, politics, culture, economics, and technology, changes which have seen the craft and labor of farming transform with them. Today, for instance, farming in the (over)developed[2] world is

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[1] This "agricultural" number does not include the 22% of non-grazed "forested" lands, lands which could arguably be included in that number when considering that somewhere around 67% of those forests are owned for "production," aka logging and timber. Such forests are effectively no different than agricultural lands growing corn used for ethanol, or hemp grown for fiber, etc., and I would argue for their inclusion in the broad definition of "agriculture."

[2] Development is a motive categorical concept in the liberal capitalist geopolitical order. Nations are measured by various actors using 'development' indices which group states into "developed" vs. "underdeveloped" categories. Underdevelopment's antonym is not development, however, it is overdevelopment. Developed nations, overwhelmingly European / Western states, did not achieve development in a vacuum, but through centuries of accumulation, extraction, and dispossession of wealth (by any definition) and labor power from other lands and peoples, chiefly through imperial and colonial systems of political, economic, social, and cultural coercion and hegemony. Consequently, and if we operate from the assumption of the equality of peoples and a basis of

augmented by fleets of highly specialized, self-propelled vehicles like combine harvesters, multi-purpose tractors, complex applicator tools like center-pivot irrigators, climate-controlled silos, and similarly cutting-edge machinery and infrastructure. Farmers have similarly used advanced machines like airplanes, robots, and satellites in agricultural roles for decades. Plants and seeds are genetically engineered from crown to root, exquisitely crafted to better suit their existence as commodities. Research programs pursued at national and international scales have created myriads of specialized fertilizers and pesticides, offering growers the ability to shape the soil's character to suit their needs. From the nuclei of seed cells to global sensors orbiting the Earth, modern conventional farming in the United States is characterized by more complex technologies and techniques than at any other time in human history.

What, then, could Hediger possibly have meant by "dark ages?"

In many ways, this dissertation is an effort to understand that question and its implications. Not only in terms of a literal answer, but to understand the assertion itself, and the constellation of assumptions, problems, and questions it embodies.

Indeed, on its face, such a question is easily answered: our farmer was implicitly referring to a set of digital and media technologies, techniques, and discourses collectively known as precision agriculture (PA), of which drones are a part. *Precision agriculture* names a suite of farming technologies and techniques which, its advocates argue, will help mitigate the negative environmental effects of conventional farming, while helping guarantee food security for a rapidly growing world population. In PA, farmers employ things like digital sensing, big data

historical understanding, "development" of certain states has been at the expense of others, which have remained comparatively "under"-developed. Therefore, a more accurate term for such global-historical beneficiaries of imperial and colonial extraction is "over"-developed states, as this term signals the historicity, the non-clinical, non-objective, non-externalized nature of the costs of developments borne by other peoples, plants, animals and lands.

analytics, and similarly complex technologies to evaluate and manage their crops, livestock, and operations at formerly impossible scales and indices of detail. Characterized by devices like variable rate seeding machines, RFID-tracked cows, GPS-guided robotic harvesters, crop-monitoring drones, and even disease-identifying neural networks, PA is among other things a major driver of rural broadband development, and so is an often overlooked, but central, force in the spread of the Internet of Things to previously unmediated environments; it, in effect, represents a major mediation *of* "the" environment, of millions of square miles and countless nature/cultures writ large (USDA 2007; van Es 2016). Proponents assert that the more granular information PA technologies make available translates to greater control over inputs and costs, in turn shrinking agricultural pollution while increasing productivity (Smith et al. 2013). Instead of treating entire fields at a time, for instance, a farmer can precisely target problem crops while also exploiting the best-producing areas of their land more effectively, in theory generating significant economic and environmental savings (Bongiovanni and Lowenberg-DeBoer 2004; Pierpaoli et al. 2013). This confluence of cutting-edge digital technology with the promise of real savings in labor, inputs, and pollution, combined with a vision of greater control in an undeniably difficult and unpredictable profession, has led a growing number farmers to invest in harvesting data along with their soybeans. It has also led to some striking claims about precision agriculture, up to and including its portrayal as a major agent of historical change.

In fact, advocates of precision agriculture rarely miss a chance to call it a revolution: a "big data revolution" (Sonka and Chen 2015), a "big data revolution on the farm" (Wihbey 2015), a "green data revolution" (Fischhoff 2016), the "third green revolution" (CEMA 2016), or, simply, "the next great agricultural revolution" (Powell 2017). What these characterizations hold in common is a vision: one in which world population has risen to nearly 10 billion people by 2050, and global food production has to double in order to keep the world fed and secure. Achieving this, such advocates point out, will not be easy – food production must grow by 100% while also reducing its net impact on the environment to head off ecological catastrophe. In short, farming is ripe for what technologists like to call "disruption," the infusion of digital technology and data-driven know-how that will reorganize current methods around more purportedly efficient and empirically sound, evidence-based practices.

A persistent recourse to revolutionary ideation is one result of this vision. A closer, more rigorous look at the complicated mix of forces driving precision agriculture, however, reveals that its benefits appear more ambiguous, and likely to be less evenly distributed, than current accounts claim. Moreover, a thorough, critical analysis suggests that precision agriculture's emergence carries potentially serious *negative* implications for social equality and environmental health, including job loss and social disruption through automation and the persistence of a fundamentally harmful agricultural-economic system. My dissertation explores these issues, placing precision agriculture in the historical and social contexts often lacking in popular accounts, context necessary to achieve a more thorough, responsible understanding of what PA offers and portends.

Therefore, precision agriculture – what it is, how it developed, and why it matters – is a concept and a practice at the heart of this dissertation. It would be a mistake, however, to understand PA as the true object of my project; wrong in the same measure as would be accepting the narrative telos of Jean Hediger's medieval ideation, tongue-in-cheek though it was. Contrary to the often sweeping, determinist, and weakly historical frames through which PA is regularly and publicly rendered, I argue that precision agriculture is, properly speaking, better understood as an epiphenomenon or a result; a material and conceptual recapitulation of deeper and more diffuse historical forces than those expressed by conventional techno-determinist metanarratives. I show how the concept and practices of precision agriculture have emerged out of a particular ontological and epistemological milieu, or way of seeing; one which information technology, capitalism, and the birth of the modern state have both produced and inhere within. This milieu has had specific and identifiable social, cultural, and political effects as it developed historically I trace over the course of my study. By examining these effects and this history it becomes possible to understand the crystallization of *precision agriculture* as a concept to begin with – what has made it compelling, lends it force, and further, what this array of technologies and practices may produce in turn.

In essence, this is the goal of my dissertation: to offer a thoroughly historical account of precision agriculture's development, articulation, and expression, and so to situate it more explicitly in relation to the complex and shifting array of material and ideological forces that have seen it emerge conceptually and technologically. How precision agriculture, as both a technology and a concept, is understood, supported, developed, deployed, and used today has real and potentially wide-ranging political and environmental consequences for both our present and future. Take-up of this concept and its attendant technical manifestations is already having significant effects within the commercial, practical, and cultural tableau of conventional American farming. Such an important development in so critical, wide-reaching, and impactful a domain cannot simply be left to the devices of its boosters, and not only because its utopian popular treatment warrants serious and dedicated criticism if its possible harms are to be anticipated or countered. The real possibilities and potential benefits of precision agriculture also deserve to be taken seriously, something that cannot be meaningfully debated or discussed *without* a thorough social, cultural, political, environmental, and historical understanding of the problems, processes, and forces that inform it. This dissertation cannot possibly hope to encompass the full measure of any one of these areas; my hope, however, is that it *can* offer an initial historical framework, and critical starting point, to help begin and inform such discussions.

In short, this dissertation offers a study of precision agriculture as the introduction of an informatic ideal in farming. Its chief argument is that, contrary to the revolutionary rhetoric marshalling and organizing the imaginaries of precision agriculture, the discourses and technologies of precision agriculture are anything but. They are evolutionary, explicitly designed and dedicated not to completely transforming, but to shoring up the conventionally industrialized, capitalist, (neo)liberal agricultural order dominant in the United States through the implementation of information and media technologies. Precision agriculture is in fact the name for an emerging informatic ideal in "conventional" (i.e. industrialized, factory-form, capitalist) agriculture that follows from the emergence of an earlier "industrial ideal" in farming that helped established that very form *as* conventional in the first place (Fitzgerald 2003). This industrial ideal, I argue, is motivating and enabling the digitization of rural or natural spaces/phenomena in previously unknown ways. This thesis offers a preliminary study of the informatic ideal in and as precision agriculture: it is an effort to historicize it, and to describe certain of its significant effects through and with the disciplinary perspectives of Media Studies and Science and Technology Studies. Put as a question, this dissertation in effect asks "what does the adoption of cybernetic/information theory perspectives and technologies produce in the realm of agriculture, and what were the conditions of possibility for this adoption and these effects?"

In the simplest terms, I argue that three co-productive historical phenomena are responsible for developing, shaping, and maintaining the milieu out of and through which *precision agriculture* has emerged: 1.) the development of a capitalist world-system of accumulation and production, 2.) the emergence of economic and governmental political technologies of control and police tied to the crystallization of the nation-state form, and 3.) the birth of modern cybernetic-information systems of scientific epistemology and technological innovation, particularly those related to digital and information technologies. These richly interrelated ways of seeing, knowing, and living have come to dominate, order, and organize productive activity around the globe, and so have played a leading role in mediating not only relationships among people, but those between humans and the broader totality of Earthly life itself. Seen in this light, precision agriculture is essentially but one specific approach, in one area of human activity, to regulating, abating, or overcoming some of the more pressing socio-economic and environmental crises caused by the very historical conditions necessary for it to exist in the first place.

If the thickly entangled historical co-production of capitalism, the state, and techno-scientific epistemology created the conditions for precision agriculture, I see what Cukier and Mayer-Schoenberger (2013) call *datafication* – the translation of social action into quantified data – as its most immediate catalyst. I use datafication here as shorthand for both the spread of digital technology into all sorts of areas and activities on one hand, and for the mix of scholarly concepts developed over the past decade or so to grapple with these changes on the other. These latter most obviously include terms like "big data," "dataveillance," and other data-appellatives, but in my reckoning they also encompass the genre of algorithm-oriented concepts ("algorithmic culture," "algorithmic life," etc.), the notions of "evidence-based" or "data-driven" thinking and practices, and the trends toward "personalization," where terms like "targeted," "precision," and "smart" are used as prefixes or proxies for, basically, "computerized," as discussed in Chapter 1. For all their differences, each of these concepts and the material-discursive assemblages they signify stem from or refer to a shared group of historical developments, most immediately related to what I called the birth of modern techno-scientific epistemology above. Specifically the mid-20th-century elaboration of Turing machines, cybernetics, and information theory, crystallized and lent force to a new way of understanding being itself. When regarded together, the myriad, wide-reaching tangle of socio-cultural transformations signified by the herd of digital concepts corralled above resolve into a relatively consistent, definite form, one usefully understood in terms of what Raymond Williams called an emergent "structure of feeling" (1977). I argue that precision agriculture is best apprehended through such terms; that is, as part of a broader emergent phenomenon of digital mediation designed to afford greater and more granular abilities to control and govern "nature," of which the precision-agriculture equipped "data farm" is a central part, itself a late material-discursive heir to those older legacies of capital, state, and science.

II. Research Methods

This critically-oriented, empirically grounded thesis employed two basic methodological approaches in researching this topic and generating new knowledge about its subject. First, it employed ethnographic methods – interviews, field recordings, and participant observations. Funded by a National Science Foundation Doctoral Dissertation Research Improvement Grant (Grant #1755078), from 2017 to 2019 I conducted some 40 variously semi- and unstructured interviews with a variety of sources, including US farmers in the Northeast and Midwest, US Extension Service and Research Station scientists, US Department of Agriculture (USDA) employees, academic and industry researchers of food and farming systems, equipment dealers, and agricultural businesspeople. I also performed participant observations on US farms in these aforementioned regions, especially on large dairy farms in Upstate New York and conventional field crop farms in Ohio and Indiana, and attended several industry and academic conferences in the United States and Canada organized around the issues of precision agriculture or digital technology in farming.

Data was collected as field notes, and in the form of audio, visual, and audio/visual recordings. The notes collected from interviews with farmers were either recorded and transcribed, or written manually. These interviews focused on the uses for which farmers employ PA, which PA technologies they choose and why, and how they understand and discuss PA (e.g. what qualities are emphasized or dismissed, what terms, metaphors, or other figures of speech are used). Data from these notes have been analyzed against one another in order to compare similarities and differences in use and opinion, and the ways in which PA technologies are understood as practical and discursive objects at different farms in order to better understand what are accepted as truths and facts about PA at different sites and in different contexts.

As a participant observer, I observed, joined in with, and recorded presentations, conversations, discussions, and debates that do not always enter into formal publications, marketing materials, or press coverage. Using participant observation I gathered information on individual motivations and rationales, as well as my subject's situated understandings of concepts central to PA such as progress, efficiency, ecology, digital/information technology, knowledge values regarding food or farming, and "precision agriculture" itself. By building a collection of everyday categories, vocabularies, taxonomies and opinions through observation, I developed an analysis of the cultures and politics informing the framing and implementation of PA that is critical to this project.

Second, I relied on critical methods including archival and historical research, critical discursive analysis, literature review, and engagement with scholarly theory common to Cultural Studies, Media Studies, Science and Technology Studies, the History of Technology, Environmental History, critical work on food and farming systems chiefly drawn from scholars of Sociology and Geography, and Critical Algorithm/Data Studies.

I undertook critical discursive analysis on information gathered from literature and historiographic reviews, participant observation, and interviews. I define critical and discursive analysis as an approach to information emphasizing the positioned, historical dimensions of its creation, viewing information and meaning as constantly evolving products of contestation and difference within social and cultural practice (Cf. Foucault 1972; Williams 1977, 1983). This approach is epistemologically focused, with political and ontological dimensions of analysis. I analyzed the materials outlined above in order to locate and develop their epistemological patterns or commitments, considering questions including 1.) What are framed as facts, truths, or common sense regarding precision agriculture? 2.) When and where do these appear? 3.) How do these discursive features change or endure across the communities concerned, including farmers, businesses, governments, and the broader public?

Finally, I also performed limited archival and historical research on primary documents; chiefly for Chapter 1's discussion of *broadcast*, and for planned sections of this study regarding technologies of mapping and land organization that were ultimately cut for the sake of time and brevity. For more detail on the research approach and results of this project, consult Appendix A.

III. Outline of Chapters

The findings of this study have been organized into four body chapters, an introduction and conclusion. Chapter 1, "Agricultural Techniques," considers precision agriculture as a major step towards the "mediation of nature," and consequently is intended to answer the question "what can Media Studies offer critical scholarship on precision agriculture?" To do so, I make an argument for a Media Studies of Agriculture rooted in the emerging field of Environmental Media Studies, and building off of important earlier work in Communication on its historical-conceptual imbrications with agriculture. I base this argument two points of connection between media and farming; the notion of a *broad-cast* common to both, and the advent of *kulturtechnicken* or "cultural techniques" in Germany, an analogue of "environmental engineering" in the United States. Using the concept of *broadcasting,* I outline a shared history of two culture industries – farming and media – that developed from a technological orientation to masses, to one of precision as their respective commons, earthly and aethereal, were enclosed following techno-scientific developments propelled by the advent and spread of capitalism and the (often, but not exclusively liberal) nation-state. I then suggest ways in which the development of *kulturtechnicken* by scholars of German Media Studies into an influential contemporary apparatus might be fruitful for further explorations of the agri/culture industry.

Chapter 2, "Precision Agriculture," defines and describes that concept as both a discourse and a socio-technical system. This chapter is intended to introduce and familiarize the reader with what *precision agriculture* signifies, to help them understand its technical and technological dimensions in order to better understand its social, political, economic, environmental, and related effects and implications. One significant effect of precision agriculture, I argue here by way of this systematic description, is the reorganization of the farm into the data farm, the epistemological reconstitution of agricultural objects, *techne*, forces, and relations upon a common informatic tableau.

Chapter 3, "The Informatic Ideal," is chiefly dedicated to elaborating the core argument and conceptual framework of this study through the description and critique of the dominant, "revolutionary" imaginary that characterizes precision agriculture discourse. I situate this discourse in the historical context it lacks and is often used to eschew – that of the historical development of capitalism and the advent of the liberal nation state. I argue that far from disruptive and revolutionary, precision agriculture represents an intensification of a centuries-long history of rationalization, technological innovation, and efforts to achieve greater productivity in farming as in every other industry, a history organized and chiefly propelled by the advent of capitalism. Understood in this light, I contend that precision agriculture is better understood as the next step in the same process that introduced the "industrial ideal" in farming as described by Deborah Fitzgerald, the contemporary "informatic ideal" developed over the latter half of the 20th century in the wake of cybernetics and information theory's enormous social and intellectual influences.

Finally, Chapter 4 draws on my field research to present two key findings regarding the development and effects of precision agriculture on contemporary American farms: the rising and complex importance of agricultural data on the farm, and its role in the emergence of supply chain "transparency" and "traceability" as increasingly significant concepts and socio-technical systems in farming. Finally, I frame these findings in terms of what I characterize as efforts to achieve a more thorough and complete "government of nature," a notion I elaborate through a discussion of precision agriculture as a kind of algorithmic dream of control, of "code as law as police des grains." I then briefly present an alternative framework to that of precision agriculture as an ever-tighter and more extensive system of police, arguing for what I see as the opportunities and possibilities afforded by the spread of computational and media technologies into agricultural and rural environments, before summarizing and concluding this dissertation.

CHAPTER 1: AGRICULTURAL TECHNIQUES

TAKING A "WIRELESS" MESSAGE FROM A TREE.

The receiving apparatus is connected with the tree by means of two nails, to which are attached the wires [3]

[3] "TAKING A 'WIRELESS' MESSAGE FROM A TREE. The receiving apparatus is connected with the tree by means of two nails, to which are attached the wires." "Tongues in Trees," 05 March 1905, *New-York tribune. [volume]* (New York [N.Y.]), Chronicling America: Historic American Newspapers. Lib. of Congress. https://chroniclingamerica.loc.gov/lccn/sn83030214/1905-03-05/ed-1/seq-21/.

I. Tongues in Trees

In March of 1905, the *New York Tribune* published an article entitled “TONGUES IN TREES,” which opened with a fantastic claim: no longer, it declared, was it “mere fancy that trees can talk. It has at last been shown that they do have powers of communication and that they are able to convey messages over several miles of intervening country” (Tongues in Trees 1905). Alluding to talking trees in Shakespeare, the Book of Judges, and the Priests of Dodona among others, the author contends:

> The language by which trees may communicate with each other is not the sound of the wind in their branches … Real “tree talk” consists of vibrations that … are the waves of wireless telegraphy, to which, it has been found, trees are peculiarly sensitive … a wireless system of tree telegraphy has been introduced into the army which compels trees to talk to one another and issue commands and take orders, even in the midst of battle, if need be (Tongues in Trees 1905.).

The article was published during a period in which the early development of ‘wireless telegraphy’– i.e., radio – was famously marked by a number of national and commercial attempts to establish the first “empire of the air.” During the period from roughly 1890 to 1920, entrepreneurs competed to instrumentalize the newly described “ætheric oceans” of electromagnetic radiation, recently understood to permeate and influence all matter (Douglas 1987). This discovery was distinctly unlike other understandings of entangled or enchanted worlds of woodland communication; it was not of chemical languages spoken through the media of root and air by trees themselves, but a kind of military Galvanism (cf. Kimmerer 2013, Kohn 2013). A lieutenant in the US Signal Service, seeking ways to put the inchoate technoscience of wireless communication to military use, found that the innate electromagnetic conductivity of living trees made it possible to enlist them as antennas in a martial media system, reliably transmitting radio signals for up to three miles (Tongues in Trees 1905).

Yet because "wireless messages, whether masts or trees be used, *are always sent broadcast*, so that a foe as well as a friend may hear," the Signal Service had also "adopted various codes, the keys to which are a profound secret to the outside world" in order to conceal them (Tongues in Trees 1905; emphasis mine). In this, the brief *Tribune* article illustrates developments in literally mediating the natural, nonhuman, and wild, largely in order to make them more available to government, culture, and capital, developments already well underway by the turn of the 20th century. Moreover, these efforts were part a broader industrial social-economic context in which new media techniques, including *broadcasting* itself, had begun to take shape.

The author's use of *broadcast* in this article is significant in this respect. At this time *broadcast* is caught, so to speak, *in media res,* between the explicitly agricultural context from which it emerged, and the looming media-industrial context it would not only shortly come to inhabit, but would help to define as an industry itself. Within twenty years, a term that had long signified the scattering of seeds would soon be sowing fruit in different pastures, at the behest of a new and different kind of culture industry, one bolting from the recently mapped plains of aethereal electromagnetism.

Over a century later, a relatively recent techno-industrial development is once again blurring the relations of nature and culture: the socio-technical system known as *precision agriculture*. Where the term *broadcast* suggests a formal, even literary relation between two critical domains of human culture and *techne* – media and agriculture – with the advent of precision agriculture, we may say that link is now simply literal. Accordingly, at a time when conventionally-producing US farmers use digital media technologies from industry software platforms, to tracking apps on worker smart phones, to bovine butt-recognition cameras (Jafari et al. 2018) in nearly every aspect of their workday, a media studies of agriculture is obviously not just warranted, but due.

To that end, precision agriculture is perhaps best understood from a media studies perspective as inhering within a broader web of developments in "environmental media" over the 20th and 21st centuries. Yet despite agriculture's importance in the emerging development and use of environmental digital media and socio-technical systems today, it is also arguably among the least explicitly studied from a media studies perspective.

There are many significant connections between media and farming, both current and historical, that media scholars are especially well-suited to address. Precision agriculture, for instance, extends novel processes and forms of mediation into rural agricultures and nonhuman environments alike. This techno-political phenomenon of mediation aims to produce a kind of government of nature. The problems it aims to solve are spurred by capitalist and state imperatives to maintain social order, chiefly by staving off falling profits and plateauing agricultural productivity with, as its proponents contend, new forms of efficiency that will mitigate the increasingly evident consequences of ecological destruction and climate change (e.g. Itzhaky 2021). Precision agriculture thus represents the expansion of well-studied cybernetic epistemologies and apparatuses of surveillance and control into new realms and activities, an ongoing and intensifying dissemination of media *techne* into the flora, fauna, and firmament, earth, woods, and waters of our world. Its unfolding is already responsible for an array of social, cultural, economic, and political effects.[4]

If the discursive and technical apparatus of *precision agriculture* serves as a medium for media technology into rural spaces and natural environments, what might this mean? What does

[4] See references in following section, beginning with Wolf and Wood 1997.

such mediation effect? What is its history? What are its consequences? In this chapter, I advance an argument for a media studies of agriculture by highlighting two illustrative historical connections between these areas. First, I explore the relationship between the martial figure of *precision* and the agricultural heirloom of *broadcasting*. I then close by emphasizing *Kulturtechnik*'s agro-media genealogy as a useful foundation for future work in this area.

i. The Environment of Environmental Media Studies

Wide-scale integration of media technology in contemporary agriculture represents among the most important emergent and developing fields of not only environmental media, but—given the dire ecological and social consequences of further environmental ruin and the significant role of capitalist agriculture in producing such phenomena—of media *in general* today. Precision agriculture has been productively and critically studied by a range of scholars in the social sciences, including Sociology, Geography, Anthropology, and Science and Technology Studies (e.g. Wolf and Wood 1997; Carolan 2016; Bos et al. 2018; Rotz et al. 2019; Fraser 2019; Gras and Caceres 2020; Marquis 2020; Legun and Birch 2021). Despite its significance in the development of rural and environmental media however, little attention has been paid to date from the perspective of media studies. Given the profoundly mediated nature of precision agriculture, I contend media scholars are uniquely positioned to offer essential critical insights into the modern mediation of corn, cattle, pickers, pluckers, soil and slaughterhouses, as well as further historical entanglements of agriculture and media.

All disciplines have demarcations, but the hedgerows enclosing Environmental Media Studies [EMS] are far from full-grown. Siting the study of agriculture in this field nonetheless turns out to be surprisingly tricky: its definition is openly contested, and its character changes with even the slightest shifts in perspective. Among the Environmental Media Studies possible at present, for instance, are those concerned with issues of media and 'the environment,' e.g. environment*alism* and the "Anthropocene" (Shriver-Rice and Vaughan 2020), as well as media studies of *representations of* "the" environment, as in moving image or digital "ecomedia" (Cubitt 2005). EMS might also include work on ubiquitous, pervasive, augmented, or ambient computing/media, a rural continuation of extant work on cybernetics and surveillance, or "smart" cities and homes (Crang and Graham 2007). It might involve studies of media environments – aka *media ecology* – as exemplified by Fuller (2005), or work on media *in* environments – media infrastructures as socio-politically propelled environment-making, so to speak – as in the work of Parks (2005), Starosielski (2015), Schwoch (2018), or most recently Hallinan and Gilmore (2021). EMS could equally well define research on the material realities of media as a productive activity, as in the works of Bozak (2011), Parikka (2015), and Cubitt (2017); here, there would also be clear kinship with related STS work on computing and the environment, like that of Edwards (2010), Ensmenger (2018), and Mullaney et al. (2021). It is easy, too, for EMS to at once signify inverse approaches that either see media as ontological environment (the Toronto School; so-called German Media Studies; 2nd and 3rd order cybernetics-inspired discourses in general), or environments as media (Peters 2015; Jue 2020; Starosielski 2021); the latter "elemental" form offering an especially necessary, affecting, and revelatory approach. Finally, we might define its purview as the mediation of environment: media as the medium of environmental observation, surveillance, and/or control, i.e. as a governance of nature, for instance, as in the literal media ecologies critically studied by Benson (2010), Braverman (2014), and Gabrys (2016; 2020) among others.

The approach taken here is most closely akin to this last definition, while sharing ties with the aforementioned "ontological," "elemental" and "smart" lineages. Precision agriculture as a discourse and a socio-technical system is intimately connected to the same capitalist and state imperatives driving the development of various new techno-colonial gardens: smart forests, wired wildernesses, and marine (as) media. Yet, like these, agriculture has its own profound historical, semiotic, and political specificities, which have at times even been identified as the technical *a priori* of culture itself, the very medium that transports the "human" from the "non," corrals the civil from the *sauvage*, refines the rustic, defines the city *contra* country – *colony* and *culture* are, after all, both children of complex *colere*, the name of the domestic cult of habituation, beating heart of empire, and dwelling of care (Williams 1983; Siegert 2007).

Following from the above, it is worth finally asserting that an agricultural media studies can and should not consist of an approach that boils down to Media + Agriculture. Rather, as this chapter argues, the epistemological and technical connections linking media and agriculture in general and *precision*, *broadcasting*, and *Kulturtechniken* in particular, run as deep as the roots of modernity.

II. *Precision* Targeting and *Broadcast* Masses

In short, there are pressing social, political, and environmental reasons to develop a media studies of agriculture, and more specifically, a critical account of precision agriculture that deals directly with the media technology and socio-cultural technics that assemblage hinges upon. One place to begin such an analysis is with the very term heralding the mediated nature of precision agriculture, *precision* itself. Why "precision?" There are many other current and possible names for computerized, mediated farming, from the "cyberfarm" of the 1990s (Sonka and Coaldrake 1996), to contemporary appellatives like “digital agriculture” or “smart farming” (e.g. Van Es et al. 2016). While in some circumstances *precision agriculture* can signify a more specific context, i.e. sub-field management of field crops in contrast with a more general process of digitization in all areas of farming at present, *precision* so far remains the most common terminological catchall for digitized, datafied, contemporary farming.

i. Precision

The notion of *precision* first emerged in European discourse during the 18th century, with an “explosive growth” in its popularity propelled by “the need for centralizing states and expanding commercial enterprises to regulate extensive human and material resource” beginning in the latter half of that century (Wise 1995a, 6). Wise (1995a, 4) defines *precision* as an act of “extending control,” initially in part through the reification of quantities. *Precision* is consequently best understood not in the colloquial sense as the achievement of some sort of objective, natural, or inevitable material perfection of tool or process, but most fundamentally as an act of valuation, intrinsically embedded within a complex of cultural values that determine such quantities in the first place.

The history of *precision* so understood – as a social apparatus – is entwined with the concept of standardization, and possesses a complicated relationship with the notion of *accuracy*. Both of these associations play a critical role in the contemporary adoption of *precision* as a prefix in a widening array of fields over the 20th and 21st centuries. Its initial popularity was related to the “enthusiasm for precision instruments and numbers” necessary to both regulate increasingly quantified objects and phenomena within realms, and to orchestrate international activities of empire, whether commerce, war, or colonization (Wise, 1995a, 4).

Historically, *precision* tended to convey something like 'reproducible exactingness:' *precision* understood as the rightness of a result or action as the consequence of reliability *qua* consistency and control. This is opposed to rightness as a function of *truth*, which is more closely associated with "accuracy." *Precision engineering* is emblematic of this former usage. The distinction is not especially sturdy, however; any closer look at the social nature of standards, reliability, or even the etymology of "right" reveals that *accuracy,* and so truth values, are never far away (Hacking 1990; Wise 1995). The history of navigation, for example, vividly illustrates *precision*'s semantic fluidity about this axis, as well as the broader semiotic and historical context of the pursuit of precision itself. It offers both countless examples of precise mechanical craftsmanship necessary for the creation of reliable, accurate navigational technologies like telescopes, chronometers, and sextants – the tradition of *precision engineering* – as well as the contextual and subtextual motivations for the development of such implements, namely accurate navigation itself, overwhelmingly pursued in the name of commercial and political power. This latter context of precise navigation in the name of European/white/Christian empire and capitalist accumulation fits comfortably within the ballistic or spatial tradition of *precision targeting*.

This indistinction helps account the nature of *precision*'s use in the later 20th and 21st centuries, as in *precision agriculture, precision medicine*, or *precision education*. *Precision* of this type represents a promise of digitally effected *efficiency*, to "both identify and extract previously unknowable surplus value . . . through mass customization via data aggregation," and conveys the strong, if mistaken, discursive connotations of objectivity commonly associated with both computerization and quantification (Kuch et al. 2020, 527). In this tradition, *precision* speaks less to an engineering sense of perfect consistency and exacting tolerances than one of accurate *targeting*, as in *precision bombing* or *precision munitions* – 'correctly' parsing masses for particulars or reliably identifying individual elements out of whole environmental ranges.

The martial lineage of precision as a kind of ballistic accuracy or process of correct identification and targeting represented by these phrases is key to understanding its contemporary semiotic character, and its more general social adoption as a prefix for processes or technologies that are computerized and datafied as in the examples above. One important point of entry for *precision* into the modern military rhetoric of targeting stemmed from the experiences of stagnation, stasis, and misery precipitated by trench warfare in World War I. This experience contributed to interwar military doctrines designed to prevent the possibility of a future war unfolding along similar lines, including the philosophy of *Blitzkrieg* warfare in Germany and an emphasis on aerial bombardment in the United States (McFarland 1995). The development of airpower following the First World War led to different philosophies of how best to design and use strategic-scale bombardment, and consequently of the adoption and employment of *precision* into a military discourse around questions of accuracy and targeting.

World War I saw the first widespread use of aircraft in military roles, and US experiences of airpower in that conflict made it clear that in addition to aerial surveillance and tactical close air support of ground units, strategic bombardment would play a defining role in future conflicts. Aircraft created a new opportunity in that they "laid bare" the otherwise inaccessible interior of enemy nations, and so made viable attacks on manufacturing, industrial centers, supply chains, transportation networks and similar logistical targets with strategic-scale consequences. Airpower was a focal point of the influential philosophies of "total" war on both civilian and military targets developed during the interwar period, especially those advanced by Italian general Giulio Douhet in his 1921 treatise *Command of the Air* and American colonel Billy

Mitchell, leader of US air forces in World War I and author of the 1925 book *Winged Defense*. Both saw air power as the axis of future warfare – especially as a psychological and industrial weapon against enemy manufacturing power and morale over and above the defeat of standing armies in the field (Laine 1991, 8-9). These men and similar advocates advanced a philosophy of indiscriminate 'mass' or carpet bombing toward such ends – dropping thousands of bombs over large areas in order to cause widespread destruction – effectively promoting total war terror attacks on civilian and military targets alike as a means for quickly and decisively ending conflicts by crushing morale and will to resist. This philosophy, predicting the doctrine of nuclear Mutually Assured Destruction in both object and effect, argued that mass aerial terror attacks would either present a threat, or a reality, so terrible that any nation subject to them would quickly overturn their government and sue for peace, eliminating the necessity for ground attacks. Strategic "area" bombing of this type advocated by Mitchell, Douhet, and others was the dominant philosophy among advocates of airpower through the 1920s. By the 1930s however, the notion of strategic mass bombing by night had lost popularity in the United States in favor of the concept of so-called "precision" bombing, or attacks upon *specific* infrastructural or logistical elements of the enemy's ability to wage war to be carried out in daylight – a necessary condition for 'precise' target identification. The notion that attacks on infrastructure would ruin enemy military capacity and shorten or end wars, known unofficially as "industry web theory," was effectively codified in the pre-war Air War Plans Division "AWPD-1" plan of 1941 and pursued by the Allies during the initial phase of the air war in WWII. It called for both figuratively and literally targeted attacks on logistical, non-civilian targets critical for enemy military function. Figuratively, in that the doctrine limited itself to targeting the material and logistical ability of an enemy nation to wage war, vs. the philosophy of submission via terror attack. Literally, insofar as such targeting required achieving the material precision necessary to hit the desired target and not another – like a factory in the midst of a crowded city. This document, like its successors, explicitly referred to such a strategy as *precision* bombardment.

This moment represents a key juncture in the evolution of the semiotic martial heritage of *precision* in relation to *targeting* that has so inflected its contemporary usage in reference to, essentially, digital augmentation of otherwise non-intrinsically computational activities or tools. The Sperry gyroscope is the material embodiment of that juncture. Precision bombardment is predicated on the ability to target, and targeted bombardment requires both a stable, reliably guided aircraft and instruments for accurate targeting. Important lineages of both technologies are rooted in separate but related research and development programs toward targeted bombardment grounded in gyroscopic technology pursued by the US military beginning in the 1910s, and accelerated by the outbreak of World War I: the aerial torpedo, the bombsight, and the automatic pilot.

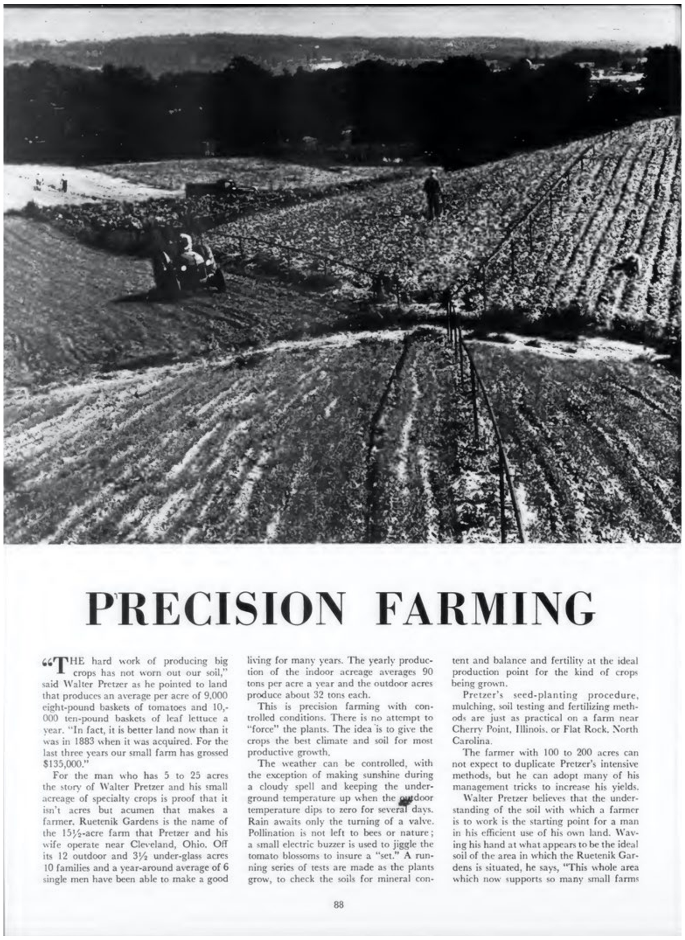
The stabilizing properties of gyroscopes had been used in aquatic torpedoes since the 19th century, and pre-war work undertaken by the Sperry Gyroscope Company for the US military on development of a flying bomb, or "aerial torpedo," had been combined with gyroscopic flight stabilization research to produce a pilotless aircraft antecedent to both cruise missiles and drones. Both the Army and Navy invested significantly in aerial torpedo research throughout the 1910s and 1920s, as gyroscopes integrated into aircraft control systems allowed aircraft – piloted or otherwise – to sustain or return to level flight automatically. This had a variety of significant military applications. Gyroscopic feedback made aircraft stable and so aerial bombardment more viable, while also making remote control of pilotless aircraft possible via gyroscopic guidance controls as would later be seen with the German V1 cruise and V2 guided ballistic missiles. It also created the conditions for vastly improved bombsight technology. By integrating gyroscopes into the sighting mechanism itself, while simultaneously linking gyroscopic feedback from the bombsight to *another* gyroscopically-controlled autopilot feedback system controlling the aircraft's flight, the Norden bombsight developed over the 1920s and 1930s made "precision" bombardment of strategic and tactical targets – contra area bombardment – at least theoretically possible. Indeed, this technological kinship between piloted aerial bombardment and pilotless aerial torpedoes reflected shifting military research investments in and arguments over the future directions of airpower. Aerial torpedoes had the potential for pilotless on-board or remote control, and so were theoretically weapons of remote precision bombardment. Piloted aircraft too could now be used for "precision" bombing, at least defined against the notion of mass terror attacks. Their development helped shift doctrinal emphasis away from Mitchell-Douhetian 'area' bombardment to that of strategic precision attacks on key infrastructural elements, playing a key role in the gradual popularization and use of *precision* in terms of highly accurate, mechanically-achieved targeting, as well as associating gyroscopic government of control systems with that term. Of these two new "precision" technologies, the US military ultimately chose to pursue piloted bombardment using Nordon bombsights, a choice that had significant consequences in the Second World War (McFarland 1995).

Following the eruption of that conflict, and the involvement of the United States beginning in 1941, major losses to Allied aircraft during daylight bombing raids necessary for using the Nordon bombsight in precision bombing ultimately resulted in significant doctrinal shifts away from the doctrine of precision bombardment, however. British forces chose to forgo daylight raids on specific targets to far more indiscriminate nighttime bombing. American bomber forces continued daylight raids, but these grew increasingly broad in their targeting, with efforts to achieve precision simply abandoned in some of the most destructive acts of the Allied Bomber Command. As the war progressed in both Europe and the Pacific, and as the promises of "industrial web theory" markedly failed to manifest in either Germany or Japan, British and American forces alike increasingly pursued an almost textbook Douhet-ian approach to strategic bombing, using incendiary and mass-area bombing infamously on cities like Tokyo, Nagoya, Osaka, Dresden, Hamburg, and Berlin to horrific effect. Nevertheless, the idea that precision bombardment of key targets both destroys morale and renders enemy fighting capacity ineffective continues to be at the core of contemporary military policy to the present day (e.g. Barnes and Stickings 2018; Suits 2019).

This martial association of precision with technologically achieved targeting was popularized by its wartime uses, as Wise et al. (1995) highlight. It developed further following the postwar advent of the electronic digital computer. The computer supplemented, transformed, and replaced discursive associations of gyroscopes with governance, control, and precision. Gyroscopic governance via feedback was itself a significant mechanical, analog precursor to the digital information science of cybernetics, itself famously born of WWII-era research into predictive anti-aircraft weaponry ("cybernetics" being *government*'s linguistic sibling, and early gyroscopes, known as "governors," highlighting associations with notions of technological and doctrinal systems named "command and control" post-war). Computers were not only technically capable of producing desired and controllable, accurate results (Mackenzie 1993; McFarland 1995), their development and adoption also helped spread a wider social faith in such results (Turner 2006; Kline 2015).

Many key postwar developments in computerized technologies of precision, such as the Global Positioning System, laser-guided "smart" bombs (Watts 2013), Operation Igloo White (an environmental network of sensors, computers and communications for directing aircraft attacks, see Edwards 1997), and early Geographical Information Systems like the Hamlet Evaluation System (Belcher 2019), were explicitly designed for accurately tracking or targeting across entire territories. It is no accident that all of the above were rooted in the context of the Vietnam War. These technological and discursive developments in precision warfare and martial-governmental control represent not only core techno-scientific foundations of precision agriculture as a socio-technical system, they helped establish its discursive conditions of possibility as well. The undifferentiated mass – whole populations, fields, areas, environments – is in this discursive lineage both *precision*'s antithesis and its condition of possibility. *Precision* of this type is defined at once by and against the mass it parses, especially through digitally mediated means.

The "imprecision" against which *precision agriculture* is defined is, therefore, the mass-area scales of industrialized farming that preceded and produced it – a topic explored in greater depth in Chapter 2. Conventional factory farming as developed in the 20th century created the conditions for 50,000 acre farms, herds of livestock with populations greater than medium-sized cities, and the input-intensive, mass-monocropped field (Fitzgerald 2003). Like the shift from *area* to *precision* bombardment before it, the *precision* of *precision agriculture* refers in part to the shift in scales of management from uniform treatments of entire fields or flocks in factory farming, to "sub-field" scales of surveillance and management where specific areas or individuals are targeted for treatment. In other words, agricultural applications of mass manufacture forms endemic to industrialization, itself a product of more primary needs for precision and standardization rooted in waxing market imperatives of improvement and the police sciences of political œconomy, in turn propelled new requirements for targeting,



PRECISION FARMING

"THE hard work of producing big crops has not worn out our soil," said Walter Pretzer as he pointed to land that produces an average per acre of 9,000 eight-pound baskets of tomatoes and 10,000 ten-pound baskets of leaf lettuce a year. "In fact, it is better land now than it was in 1883 when it was acquired. For the last three years our small farm has grossed $135,000."

For the man who has 5 to 25 acres the story of Walter Pretzer and his small acreage of specialty crops is proof that it isn't acres but acumen that makes a farmer. Ruetenik Gardens is the name of the 15½-acre farm that Pretzer and his wife operate near Cleveland, Ohio. Off its 12 outdoor and 3½ under-glass acres 10 families and a year-around average of 6 single men have been able to make a good living for many years. The yearly production of the indoor acreage averages 90 tons per acre a year and the outdoor acres produce about 32 tons each.

This is precision farming with controlled conditions. There is no attempt to "force" the plants. The idea is to give the crops the best climate and soil for most productive growth.

The weather can be controlled, with the exception of making sunshine during a cloudy spell and keeping the underground temperature up when the outdoor temperature dips to zero for several days. Rain awaits only the turning of a valve. Pollination is not left to bees or nature; a small electric buzzer is used to jiggle the tomato blossoms to insure a "set." A running series of tests are made as the plants grow, to check the soils for mineral content and balance and fertility at the ideal production point for the kind of crops being grown.

Pretzer's seed-planting procedure, mulching, soil testing and fertilizing methods are just as practical on a farm near Cherry Point, Illinois, or Flat Rock, North Carolina.

The farmer with 100 to 200 acres can not expect to duplicate Pretzer's intensive methods, but he can adopt many of his management tricks to increase his yields.

Walter Pretzer believes that the understanding of the soil with which a farmer is to work is the starting point for a man in his efficient use of his own land. Waving his hand at what appears to be the ideal soil of the area in which the Ruetenik Gardens is situated, he says, "This whole area which now supports so many small farms

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Farm Quarterly. 1947. "Precision Farming." *The Farm Quarterly* Winter 2(4): 88.

specificity, and accuracy (Neocleous 2000; Harcourt 2011). The many uses of *precision* in an agricultural context decades before the first "precision agriculture" conference in the early 1990s – as in a 1947 *Farm Quarterly* article literally entitled "Precision Farming" – speaks to this fact, as well as its increasingly popular post-war martial connotations (Farm Quarterly 1947; Wise 1995b, 354). An 1865 commentary on broadcast seeders offers another example: "Broadcast sowing machines relieve the farmer of the labor of carrying the grain … scatter it more uniformly … [and] deposit with a *far greater precision* the exact amount which he wishes to sow" (*Detroit Free Press*, 1865; italics mine).

There is also the related, if contextually distinct example of the fascinating daydream sequence in Stanislav Rostotsky's Soviet melodrama *It Happened in Penkovo* (1958), in which its protagonist young collective farmer fantasizes about his tractors transforming into a fleet of drone automatons, remotely monitored with a television control station, a blend of industrial and informatic ideals that highlights an algorithmic rationality intrinsic to both.

Precision is of course not the only term used as shorthand for computationally produced targeting, control, and/or feedback. *Personalization* and *smart* are related, significant and popular adjectives that have come to serve variably related or synonymous purposes in recent decades. *Smart farming,* for example, is often used synonymously with *precision agriculture*, as a catchall for connoting any and all forms of digitized farming. Like *precision*, it too has developed within a context of military public relations rhetoric as a synonym for digitally achieved exactingness and control, especially in reference to mediated and supposedly hyper-precise “smart bombs” as popularized by press coverage of the Gulf War (on *smart* see Halpern et al. 2017; Hong 2021). Also like *precision*, *smart/ness* is a shorthand for something that is optimal, superior, ideal – sharp not dull, dynamic not fixed, capable of accuracy or rightness.

In the broader media industries, however, the definition of computationally-parsed, individual-scale accuracy is usually referred to as a practice of *personalization*. *Precision* and *personalization*, like *smart/ness*, connote highly similar discourses, technologies, and ends in their respective uses. And, like *precision, personalization* is defined both through and against the industrially constituted “masses” of modernity, most famously *mass media*.

The “mass” media industry first emerged as such, roughly speaking, the 1920s with the establishment of radio broadcasting and Hollywood, among other key developments. That decade also saw an interesting phenomenon appear in the fields of both agriculture and media: the moment the “mass media” were born as such, for example, desires to use these media in less broadly uniform and more targeted ways also immediately begins to emerge. This phenomenon is neatly captured by the publication of Walter Lippman’s *Public Opinion* in 1922, key elements of which lamented the emerging problems posed by rapidly developing mass communication media and the herd-like public it produces, only to be succeeded by Edward Bernays’ *Crystallizing Public Opinion*, a treatise on the deliberate and targeted manipulation of the mass media apparatus through the development of “public relations,” only a year later. Where

Lippmann argued for a kind of scientific management of society by a cadre of benign, benevolent expert elites in the name of culturing democracy, Bernays's interests were aimed at a comparatively less lofty target. His great innovation in *Crystallizing Public Opinion* was the application of propaganda techniques developed for the war effort – technologies for managing the social and ideological tenor of a wartime public – to public and commercial mass media and communications on behalf of a given, private interest. In this and related works, Bernays effectively outlined the nascent fields of marketing and public relations, reflecting a broader trend in industry and business in the 1920s. Marketing and PR effectively represent a desire or dream to govern the market itself, to protect one's interests from risk by limiting the complexity of the market and confusing agency of consumers. Or, more accurately, by carefully delimiting these – bounding, channeling, and reducing consumer agency, for instance, while simultaneously aiming to preserve the culturally necessary experience of commercial "choice" (Ewen 2001; Berghoff et al. 2012).

Those interested in achieving such "consumer control" used a growing body of customer data collected by businesses to identify valuable customers, attempting to kindle repeat business through what would today be called "targeted" advertising. In contrast to the "impersonal mas retailing" of broadcast advertising first via post, and later radio broadcasting, these early data miners used a newly developing technology – individual credit accounts – to "personalize mass retailing" with tailored messages to high-value customers constructed from information in their client ledgers. (Lauer 2012). Accurate information and filing systems developed for managing and storing credit information offered new ways to identify, organize, interpolate, and control the emergent "consumer" they constructed, contra the "customer" or "client;" a new form of subjectivity that reflected the mass, information-based character of marketing vs. the individual scale of local, commercial business relationships. The birth of "market research" over the late 19th and early 20th century represents an early form of data mining in all but name, expressing as it does a form of quantified governmentality in line with similar developments in other areas like the Hollerinth managed 1890 census, the 18th century "avalanche of printed numbers," and the imperatives toward identification, rationalization and quantification driven by empire and capital (Hacking 1982; Beniger 1989; Bowlby 2002; Cohen 2003).

By the 1920s the "dream of tracking individual consumers and delivering perfectly tailored and times promotional messages was already alive" and flourishing (Lauer 2012, 154). Credit managers analyzing massive collections of personal and financial data in the form of customer credit records discovered they could organize and sort the market into specific segments, practicing a distinct if early form of what today might be called "dataveillance." Critically, "while the specter of mass society loomed in the minds of early twentieth-century politicians and intellectuals, credit managers were already beginning to deconstruct it" (Lauer 166). At the very moment the introduction of new forms of mass media were contributing significantly to the production of a new sense of social mass, and with it a mass market, precursors of contemporary "targeted" marketing were already at work parsing and personalizing it.

Advertising and marketing firms famously became among the most enthusiastic industries to adopt computer technology in later decades – reflecting the pre-existing social, political, economic, and even epistemological structures already in place, conditions of possibility that made computing technology legible and attractive too these professions (Berghoff et al. 2012; Jones 2018). Today computer-based big data analytics of consumer information – i.e. digital market research – is of course a major industry in its own right, that of digital personalization, “mass customization,” algorithmic prediction, and targeting; an industry that could just as easily be called *precision marketing*. With companies like Netflix and YouTube, this process has come full circle in transforming the mass media industry itself, arguably, into a medium of mass personalization – a kind of broadcast targeting, a swarm of prediction.

In short, both media and agricultural “targeting” share a common historical context rooted in the birth of techniques and technologies of mass application, a context deeply shaped by the doctrines and technologies of martial precision. This historical kinship of precision-as-targeting is evident in the overlap of operations and effects media personalization and agricultural precision technologies have on their respective objects – how they create spaces, organize relations, and the ways that their aims/ends produce common discourses, effects, rhetoric, aesthetics. They are now manifest today in variously related, overlapping concepts and discourses of smart/cybernetic/informatic/precision discourses, in the “smartness mandate” and the “promise of precision,” phenomena that reify algorithmic normativity/rationality, cybernetic rationality, control, or what Franklin (2015) has described as a logic of “digitality.”

P*ersonalization* and *precision* are united as referents for the practice of algorithmically identifying, calculating, interpreting and predicting specific signs or phenomena, according to specific, socially constructed definitions of accuracy (e.g. “military aged males,” “patterns of life,” “recommended for you,” etc.;). We can consider these processes of massification in general, and the birth of the agriculture industry and the culture industry in the early 20th century in particular, as the conditions of new desires for precision. Mass media beget marketing and the desire for personalization, mass agriculture begets a desire for precision lost in the very process of industrialization. Masses – whether populations, data, audiences, or acres – were themselves a product of more primary state- and market-driven imperatives towards rationalization and industrialization, processes that both invented the masses that were their object, and propelled the development of precision and rationalization technologies necessary to quantify, govern, and utilize them. It is from this earlier milieu of increasing market pressures and centralizing states that the agricultural term *broadcast* first emerged.

ii. Broadcast

Among the first modern "precision" agricultural technologies to emerge was the 18th century seed drill. Moreover, the seed drill's rapid diffusion and adoption in an increasingly capitalist European agricultural milieu appears to have been a key catalyst for the initial rise of *broadcasting* itself in the Anglophone world, and with it a clear, if ostensibly figurative, early link between agriculture and media.

Broad-cast, or hand seeding, is the ancient art of sowing by scattering; tossing handfuls of seed over prepared ground. While broadcast sowing is as old as agriculture itself, the term *broad casting* only became commonplace in written English during the 18th century. The introduction of planting machines called "seed drills," particularly Jethro Tull's influential 1701 design, created a need to differentiate older broadcasting methods from these new types of mechanical sowing. Tull's seed drills used a small wheeled plow to create furrows in the soil (an act known as "drilling") into which seeds were dropped at regular intervals and depths. The adoption of Tull's device was an important step in English agricultural rationalization, and was significant to the broader processes of agricultural rationalization and "improvement" unfolding in England since the 16th century (Wood 2017).

Scant evidence of "*broad cast*" or *"broadcasting"* of any orthography exists in English prior to 1700; over the following century, however, its examples quickly proliferate. 18th century agricultural literature regularly uses versions of *broadcasting* or *broad-casting* to differentiate hand sowing from other planting methods like seed drilling, e.g.: "…when Oats are ſown in the random or broadcaſt Way, there is no more Mold allowed their roots than what the Harrows and Roll give them" (Ellis 1744, 49); "the land was got into exceeding good tilth by October, and divided into two equal parts; one was drilled at the rate of 1½ buſhel per acre; the other broadcaſt with 2 buſhels" (Young 1792, 140);); "…the difference of the preſent condition of the land of the drill and broad-caſt; the former, by ſearifying, harrowing, and hoeing, is clean, compared with the broad-caſt, and fit for a ſpring crop; the latter is foul, and fit for fallow only" (Royal Society of the Arts 1793, 38-39). To date, I have found only analogous forms of "broadcast" in earlier works, e.g. advice to "scatter abroad" or "cast abroad" as in "the corne being thus ſcatered abrode;" or "than caſte thy pees fro the all a-brode" (Fitzherbert 1767 [1531], 64, 69, 11). Whether the adoption of seed drills precipitated this change or not, printed evidence for *broadcast*'s comparative lack of use prior to 1700 and rise in popularity during the 18th century is strong, and is in either case undeniably rooted in the growth at this time of capitalist market imperatives that drove the need to achieve greater efficiency and productivity on farms.

This pressure to "improve" agriculture was tied to developments in English rural society rooted in the 16th century, namely the gradual development of capitalist, market-determined social relations which in turn contributed to growing market pressures and changing conceptions of property influenced by philosophers like John Locke, and the breakdown of previously feudal forms of agricultural production (Brenner 1976). *Improvement*'s original meaning was tied to this process; rather than the general sense of 'making things better' it suggests today, *improvement* directly and etymologically denoted a process of increasing the profitability of land (Wood 2017).

This was primarily achieved through two intertwined processes. First was the development and commercialization of “waste” lands (forests, wetlands, and other ‘unproductive’ environments), the enclosure of common lands, and the establishment of colonies, all accumulating capital to landowners and transforming earth into property, integrating it ever more tightly into an emerging legal, social, and economic market order (Moore 2015). Second was increasing agricultural profitability through greater efficiency and productivity, chiefly by developing more efficient and productive farming methods and technologies (Brenner 1976; Wood, 2017). Tull’s seed drill is one of many such technologies that emerged from and contributed to these changing conditions; others included new crop rotation systems, plant breeding practices, land drainage and reclamation technologies, and advanced surveying and mapping methods and devices (Williams 1975, 66). In short, the first mass culture was industrialized agriculture, propelled by an emerging capitalist market order and the imperatives to rationalize, mechanize, and industrialize agricultural production. *Broadcasting* – first of seeds, later signals – emerged from this process.

Novel departures from these original applications of *broadcast* began to appear in the 18th century; by the 19th *broadcast* was used both in its original role as a modifier or adverb (e.g. ‘the clover was sown broad-cast’) as well as an active verb (e.g. ‘I broadcast the clover’), with its overall use increasing as the century progressed. By 1849 for instance, American readers of the *Southern Cultivator* were admonished to spread “guano” evenly over their fields, as “nature manures broadcast” with positive results (Floyd 1849), while others inquired in the *Prairie Farmer* as to whether onions might be “successfully sown broadcast” (Birchard 1865). One farmer in 1876 wrote the editors of the *Cultivator and Country Gentleman* to note that because “all the intelligence necessary to sow with the drill was furnished by the inventor,” seed drills need no special training – contrary to the craft of sowing grain "evenly broadcast," which not only depends upon individually embodied traits like height or endurance, but is a skill that requires teaching and experience – in order to grow "fields of broadcasted grain … worth a day's journey to see" (Moreland 1876).

This verb form helped establish *broadcast* as a synonym for dissemination in general over the 19th century, and so, ultimately, public communication itself; no accident, given the seeds of dis-*semin*-ation's own agricultural etymology (the *semin* of dissemination, as *seminal*, derives from Latin *semen* or "seed," itself a Germanic word stemming from the same Proto-Indo-European root; OED 2019). Sermons, for instance, could be "collected as into a vessel of pearls to be scattered 'broadcast'" (*New York Observer and Chronicle* 1863). In their groundbreaking 1890 legal definition of privacy, Samuel Warren and Louis Brandeis chastely lamented that "to satisfy a prurient taste the details of sexual relations are spread broadcast in the columns of the daily papers" (Warren and Brandeis 1890, 196). By the early 20th century, it was conventional to use *broadcast* when describing the circulation of texts in printed or spoken forms (i.e. "two booklets … are being sent broadcast this spring;" Cunningham 1904, 17). Even people could be "sowed broadcast;" through misfortune, for instance, by the poor handling of dynamite (*Detroit Free Press* 1897, 18), or in the case of "bodies scattered broadcast" by a tornado (*Los Angeles Times* 1905, 11).[5]

That media discourse adopted the language of broadcasting and dissemination from agriculture is well established (e.g. Gripsrud 1998; Williams 2004): Peters, for instance, has argued for understanding communication as and through its roots in dissemination (1999; 2006). *Broadcast*'s loosening from agricultural signifier into general metaphor for distribution over the

[5] The former article may in fact be a joke; nevertheless, the example remains valid!

19th century was central to this later uptake into an emerging media industry's vocabulary. Certainly the use of *broadcast* to describe the dissemination of literature, which is in ample evidence by the turn of the 20th century, was an important precursor. Above all, the essential thing to note is that regardless of its etymological trajectory, *broadcast*'s uptake as a metaphor for communication was driven by a social need; its symbolic development was not due to some kind of intrinsic, self-propelled evolutionary force. Its adaptation and adoption reflected a changing society, changing political, economic, and cultural conditions accumulated over previous centuries. These changes – new relations among people and things; accelerated social reorganization propelled by the various imperatives and requirements of capital, state, and empire; the final stages in the breakdown of an older kind of society and its established traditions and orders; increasing mobility, displacement, and atomization – created new requirements for communication among both social institutions and people (cf. Williams 2004).

III. From Agriculture Industry to Culture Industry – The Enclosure of the Æther

The earliest examples of *broadcast* in reference to the newly emerging technical media of the 20th century tend to appear *with* rather than *about* it, as in the example that opened this article. To understand *broadcast's* jump from dissemination simile to the privileged title of an entire industry, it is important to recognize that prior to World War I, radio technology was basically envisioned as a more versatile, "wireless" form of point-to-point telegraphy or telephony. From this perspective, removing dependence on wire infrastructures would allow for instant communications over previously insurmountable barriers like mountain ranges, oceans, or great distances. Wireless technology promised to connect anywhere a physical link between two places did not already exist with instantaneous communication, an affordance instantly compelling to the Navy, travel, and shipping industries, among others (Douglas 1987; Marvin 1988). In other words, the original impetus for wireless transmission was that of *targeted* communications. Accordingly, the electromagnetic nature of radio transmissions to emanate indiscriminately and omnidirectionally was at first seen as a liability – a bug, not a feature. After all, no one presumably would want to use wireless transmissions for business, government or military communications, or private personal affairs if those transmissions leaked through the æther to anyone with a receiver.

Lee de Forest, an early radio industrialist from the American Midwest, was among the first to recognize the features of omnidirectional audio transmission as a material opportunity rather than a technical hindrance. He also appears to have been the first to employ *broadcast* in reference to electronic "mass" mediation by radio. While the majority of early radio systems used dot-dash signals borrowed from telegraphy, various demonstration of analogue audio transmission before, at, or around 1900 sparked public speculation about other possible uses of wireless communications, namely wireless *telephony* (Marvin 1988). De Forest conceived of using wireless technology to *deliberately* transmit speech, music, and poetry indiscriminately; or, as he wrote in the winter of 1906-7, to "distribute sweet melody broadcast over the city" (Barnouw 1966, 25). He envisioned wireless telephony as a means for democratizing otherwise rarefied experiences like opera explicitly in terms of 'broad-casting' them freely over the airwaves, in marked contrast to the overtly monopolistic endeavors of other radio innovators like Marconi or Fessenden (Douglas 1987). By 1916 for instance, de Forest had plans to introduce a "wireless newspaper" that would "bring the world's news and the music of opera stars to farms all over the country as soon as the milking is done and the cows turned out to the night pasture" (*Los Angeles Times* 1916, 11).

It took over a decade, however, for the well-established but generalized use of *broad-cast* to grow more specifically and closely associated with wireless *radio broadcasts,* or broadcast*ing* as an industry, a process that accelerated following the end of World War I. Important changes in *broadcast*'s uses became increasingly evident over the 1910's. While still regularly modified or prefaced early in the decade, as in "the music can be … *sent out broadcast*" (*New York Times* 1910, 9) or "it will be *spread broadcast* over the Atlantic Ocean" (*New York Times* 1913, 1), by mid-decade *broadcast*'s now-modern uses were increasingly in evidence. The same 1916 *Los Angeles Times* article quoted above, for example, proclaimed the "world's doings and opera to be sent broadcast" preserving the increasingly residual form, while an *Indianapolis Star* story on a U-Boat attack only weeks later exemplified is use as an active verb, describing something radio *does*: "within a few minutes the air was literally charged with electricity as wireless messages of warning were broadcasted along the coast" (*Los Angeles Times* 1916, 11; *Indianapolis Star* 1916, 1). By the decade's end this use of *broadcast* was well established.

Instances of this more modern application of *broadcast* spiked markedly after 1920, due to a series of technological, commercial, social, and regulatory developments that coalesced following WWI.[6] A more developed regulatory technological landscape, coupled with a glut of war-trained communications experts and a number of freshly minted licensing agreements among major patent-holders created the necessary conditions for the outright commercialization of radio technology (Douglas 1987). Critically, in contrast with point-to-point system that dominated radio communications from the 1890s through the 1910s, the most successful

[6] This finding is based chiefly on reviews of existing digital archives of news sources including ProQuest, Scopus, HaithiTrust, and reviews of canonical English language agricultural texts from roughly 1400 – 1900BCE, findings which are reflected by the Google nGram for "broadcast" and "broadcasting," available here. These searches do not exhaust all possibilities and there is certainly more work to be done in this area, but they provide a solid foundation upon which to assert this historical claim, and pursue such work in future.

approach for commodifying the airwaves and making wireless telecommunications profitable proved to be the "broadcasting" method first pursued by De Forest (Douglas 1987).

By 1922 the 'mass' medium of radio broadcasting was itself firmly established, and increasingly industrialized. Notably, in March of that year the *Washington Post* printed a story linking farming and radio in a new way; one in which this newly minted use of *broadcast* was employed to illustrate the insinuation of the agriculture industry with that of a now-emerging *culture* industry. Under the heading "Radio Will Spread Crop Market News," the *Post* outlined a new commercial imaginary linking farmers to radio by essentially reproducing a press statement by president of the Chicago Board of Trade, Robert McDougal, "outlining the boards' plan *to broadcast crop market reports* by radio telephone beginning Monday" (*Washington Post* 1922). The piece even introduces its topic with techno-utopian tropes almost indistinguishable from those found in contemporary reporting on precision agriculture:

> The farmer need be no more than 30 minutes behind his city brother in receiving news of the factors which determine prices of agricultural products … The radio system, which will cover a territory within a radius of 500 miles of Chicago, [will be] "the greatest forward step in 2,000 years" in bringing the farmer in contact with the factors that make the price of his product. (*Washington Post* 1922)

The remarkably non-agricultural use of the term *broadcast* that opened the *Post* article, despite the piece's explicitly agricultural subject, is a vivid and ironic example of this term's new-born sense. Now full cloven from its original semiotic referent, by 1922 *broadcast* possessed a new and unique utility of its own. No longer simply a metaphor or even a modifier, as in 'the reports will be scattered broadcast,' the *broadcast* of this passage represents an elemental semiotic transmutation in its referent from earth to æther, and exemplifies the birth of *broadcasting* as something that communications technologies and an emerging mass media industry do, as opposed to something a *farmer* does. It is similarly striking to note that while this article heralds radio as a reconciler of city and country, cattle and capital, the language of media in fact flows in the opposite direction: from the agricultures of industrializing farmlands to the culture industries of broadcast airways.

The success of broadcasting as a business model ironically helped foreclose de Forest's dreams of radio as an egalitarian mass mediator of culture. By the close of the 1920s, corporations like RCA, AT&T, Westinghouse, and General Electric, as well as the newly established Columbia Broadcasting System and National Broadcasting Company, had successfully instituted legal and commercial control over the most lucrative bandwidths in the radio spectrum. By the 1930s broadcasting had powerfully contributed to the industrialization of the æther and establishment of a new, national, *mass* media landscape.

In sum, any scholar who seeks to understand the invention of masses and industrialization of culture would do well to begin with the origins of broadcast and precision technologies alike on the farm, in the imperatives of agricultural improvement. *Broadcast* originally rose in response to the industrialization of farming in 18th century England, and from there developed as a metaphor for mass 'dissemination' in general over the following two centuries. By the 1920s, experimenters, entrepreneurs and enthusiasts of radio technology had borrowed *broadcast* from that context to describe the propagation of radio waves. As the ætherial 'wastes' were defined, enclosed, and industrialized like the woods and commons before them, this word's dominant use was gradually divorced from its primary, agricultural denotation. Along with its socio-cultural litter-mates – the medium of *radio*, and the emergent *mass/media* industry – *broadcast* became the signifier of choice for invoking the activities of an emerging socio-technical and commercial system increasingly known as *broadcasting*. Most importantly, *broadcasting* – at once a product of the processes that led to factory farming, and name of the first form of "mass" media, radio broadcasting – was thus intrinsically connected to the birth of two culture industries that hinged on the establishment of "masses," whether of crops or consumers, that in turn obliged new technologies of granularity and targeting; or in other words, *personalization* and *precision*. Or to borrow the language of Raymond Williams, trading "*television"* for "*precision farming*": "in no way is the history of *precision* a history of digital systems creating a new society or new social conditions. The decisive transformation of industrial production, and its new social forms, which had grown out of a long history of capital accumulation and working technical improvements, created new needs but also new possibilities, and digital media systems, down to precision agriculture, were their intrinsic outcome" (2004, 12).

IV. Agricultural Techniques

By the close of the nineteenth century, the long-unfolding technoscientific forces of state and capital had given birth to a mediated world in a sense developed below – a nature and society that could not only be communicated with, but cultured. New domains of being like *environments*, *ecologies*, *economies*, and *society* were invented along with the means for mediating them, making them literally available to acculturation, domestication, and government on the other. Media scholarship on this century of "wonder and horrors" speaks to various socio-cultural experiences of such developments, tensions between disenchantment and re-enchantment, life and un/death spurred by the advent of industrial modernity and its new technical media: uncanny vital forces communicated by Mesmerists and Galvanism, living mediums sprouting from the Spiritualist soil of the Burned Over district (Sconce 2000), revelatory "proofs" of the occult both natural and supernatural made possible by new technical media from the motion studies of Muybridge and Marey to ectoplasm-draped seances and fairy photographs, or even the broadcasting tongues in trees that opened this article. The world itself –

elementally, physically, socially, environmentally – was increasingly made available to science, state, and capital over the long nineteenth century by techno-scientific developments that, in essence, literally mediated the matter and phenomena of existence (cf. Scott 1998). These developments took different forms in different places. In the Anglophone world, certain of these practices came to be characterized as "engineering," as in environmental engineering, social engineering, or agricultural engineering (Fitzgerald 2003). Germans found a different word for a similar concept: "*Kulturtechniken*."

The previous section explored the relationship of farming and media through two points of basically metaphorical connection: *broadcast* masses and *precision* targeting. This approach suggests at least two possible paths of study for future work. One involves further explorations of discursive relations between the two, such as those found in *commons* or *cults*. The second would include more technologically or historically-focused studies of farm-media imbrications, e.g. of media and communications devices as used *in* farming or an agricultural context (e.g. Miles 2019) or as employed to *represent* it (e.g. Marez 2016). I will close this chapter by briefly highlighting a third—more literal, or even ontological—link between media and agriculture worth considering, one suggested by contemporary media scholarship on *Kulturtechnik* (cultural technology/techniques).[7]

The concept of cultural techniques did not originally hold any clear connection to media. First introduced in 1870s Germany, *Kulturtechnik* "saw in rationalism techniques for realizing the power and potentials of nature" (Geoghegan 2013, 75). The concept was first developed as a means for linking "the hitherto separate domains of geodesy, engineering, and amelioration, in order to respond to the need for increased agricultural output in a newly united, rapidly

[7] As developed by, among others, Germanophone scholars including Vismann (2013) and Siegert (2013, 2006), as well as interlocutors such as Winthrop-Young (2014, 2013, 2006), Geoghegan (2013), and Parikka (2013).

industrializing Germany," echoing roughly contemporary efforts and ideologies of "environmental" or "agricultural engineering" in the United States, and even in certain respects the universalizing informatic substrate of modern *precision agriculture* explored in the next chapter (Winthrop-Young 2014, 380). German "*Kultur*" has a unique semiotic history (Elias 1982); its use in this 19th century agricultural context is probably best understood "as an attempt to raise the agricultural domain into the world of *Kultur*" that blurred the distinction between capital K-*Kultur* as the best that's been *gedacht* or *gesprochen*, so to speak, and culture as a process of practical cultivation, as of *Brassicas* or bacteria (Winthrop-Young 2014, 384). This meaning was key for *Kulturtechnik*'s later 20th century migration from agricultural fields to media: German scholars interested in expanding 'media literacy' adapted the term to these educational efforts aimed at avoiding what they perceived as potentially harmful social-cultural effects of electronic 'mass' media (Winthrop-Young 2014; Geoghegan 2013). It was in this context that German media scholars focused more acutely on the tension of cultural or technical primacy inherent in the concept of cultural techniques, transforming it into a far more sweeping and generalized apparatus, the essence of which, in Winthrop-Young's words, was to redefine the boundary between nature and culture "as a zone of constant exchange that has no predetermined location;" mediated, and so produced as distinctions such, by a third agent: *techne* (2014, 383).

What the articulation of *Kulturtechnicken* allows us to see are not only the parallel and related, if distinct, developments of 'environmental engineering' disciplines emerging in the United States and Germany during the late 19th and early 20th centuries. Nor does it simply highlight striking parallels between efforts to comprehensively gather myriad epistemological and methodological discourses and practices together under the mantle of a single concept, aimed at the generalized manipulation of multiple facets and scales of whole environments in tandem – in short, to treat earth, matter, and being as the media of state and capital – as is characteristic of the concept and field of *precision agriculture* a century later. Due to the specific nature and history of this concept, it also vividly highlights the roles that *media* technologies, broadly defined, had begun to play in achieving such goals generally, and in the development of an increasingly industrialized agricultural practice more specifically. Media technology in this contemporary construction of *Kulturtechnik* communicate nature to culture, society to *physis*, in ways that at once invite and collapse that very distinction.

For 21st century practitioners like Vismann, the concept of cultural techniques affords a way for understanding "what media do, what they produce, and what kinds of actions they prompt" (2013, 83). Similarly, Siegert bases his argument that "culture is technologically constituted" on an exploration of cultural techniques, defined as "the operations of operative sequences that historically and logically precede the media concepts generated by them" (2007, 29). In this tradition, cultural techniques offer a kind of ontologically primal, broadly encompassing theory of media, technology, and culture. This contemporary usage, however, also tends to involve reifications of that boundary, an issue highlighted by the habitual fixation on a recursively agricultural origin myth for *Kulturtechnik* in the image of a plow breaking the plains, or a corral separating livestock from farmers – inaugurating the very human/nonhuman distinction itself (e.g. Siegert 2007, 29-30; 2013, 89). Ironically, these discourses invoke rather historically and politically specific European legal philosophies of property developed by, as, and for imperialist institutions of settler colonialism, capital accumulation, and improvement (e.g. Vismann 2013, 84).

These tendencies highlight some of the limits of some contemporary cultural technicians in their love of seeing *culture* and *colere* as the grand historical cut; the door of distinction between inside and outside, city and country, human and non, while ironically failing to make the more properly historical observation of culture's kinship to *colony* (and so empire), as well as *care* (and so ethics; see Striphas 2019). Nevertheless, like Geoghegan (2013) and Parikka (2013), among others, I believe there is serious potential in this media ontology of culture for grounding and orienting a media studies of agriculture that is "able to talk about such media techniques that have to do with the alternative materialities of, for instance, electronic waste and … animal studies" (Parikka 2013, 155), and avowedly reject determinist, Eurocentric, and patriarchal tendencies that characterize such constructions of cultural techniques. Blanchette's (2020) multi-faceted, careful, and creative study of the vast complex of human and non-human dimensions at play in the industrial raising and slaughter of pigs for human consumption offers an outstanding counter-example to follow on this point.

Vismann, for instance, seems to complicate her position in certain later work, in that she also sees in the affordances of cultural techniques a "turn against framing things in in strictly passive terms [derived] from an ecological impulse, demanding that non-humans be treated equally with humans and their specific rights" (2013: 86) and Siegert has highlighted the potential in exploring the strong affinities of cultural techniques and "new materialist" or "posthumanities" thinking. While these latter have at points reproduced many similar problems and limitations, in the face of a modern medi-terra increasingly enveloped in data farms, smart forests, and other environmental media, a media studies of agricultural techniques also shares in the liberatory epistemological, political, and methodological possibilities those bodies of thought have to offer. This perspective will be explored as a generative possibility, using a slightly different theoretical foundation, in the concluding chapter of this work.

V. Conclusion

This chapter has endeavored to show how the advent of precision agriculture helps foreground entanglements of media and agriculture, making them literal and obvious. I have outlined an argument that the modern mediation of farming warrants study on its own merits from a Media Studies disciplinary foundation, a perspective that offers generative insights and possibilities for such work not necessarily available otherwise. Precision farming, understood as the mediation of agriculture, represents one aspect of broader efforts towards producing a true government of nature achievable through and as a mediation of natural and environmental forces, bodies, phenomena – a line of argument covered more directly and thoroughly in Chapter 4. Consequently, I believe it is important both politically and ecologically that media scholars study these phenomena for the unique contributions they can offer.

The following chapter builds upon and explicates this point through a substantial and detailed study of precision agriculture as a socio-technical system. Digitization of the agricultural industry – from farming technology to agro-chemical suppliers to corporate and governmental management of the agri-food system itself – appears to not only facilitate but drive that inducement to govern, or governmentality, and with it, drives even greater consolidation of land and capital in a farming milieu already extraordinarily consolidated. As Chapter 2 will argue, placing disparate concepts, tools, and techniques upon the same epistemological tableau – that of information – creates a kind of inter-operable legibility that is foundational for such processes as they are unfolding today. Understanding the actual, technical elements, practices, and details of precision agriculture as a system is a pre-condition for understanding this process of consolidation and rising governmentality in US agriculture moving forward. Accordingly, Chapter 2 offers a survey of precision agriculture designed to advance this argument while orienting the reader to what that term denotes, in order to later more fully and critically engage with both precision agriculture's framing discourses and some of its key contemporary socio-technical effects.

Chapter 2: Precision Agriculture as a System

I. Introduction

As the preceding chapter argued, there are compelling methodological, historical, and epistemological reasons for scholars of media and culture to attend more carefully to the world and practices of agriculture. To facilitate these attentions, as well as to orient this study around a detailed understanding of its object, this chapter will describe precision agriculture as a technological system in detail. By this I mean two things. First, as this is an interdisciplinary work drawing together two relatively distinct families of scholarship – Media and Cultural Studies on one hand, Science and Technology Studies & the History of Technology on the other – this project has the problem of addressing separate audiences with often different methodological, idiomatic, and archival identities. For these reasons, it is useful to give disparate readers some common orientation, and to offer a useful picture of what *precision* agriculture conventionally denotes and connotes within the broader structure of *conventional* agriculture. This will involve describing and explaining precision agriculture as a technological and commercial system, a collection of parts and practices. The second purpose of this chapter will be to build on the first in order to illustrate the conceptual and discursive dimensions of precision agriculture, i.e., how this concept creates the ground upon which new modalities of knowing and seeing are articulated. In short, the second purpose of this chapter is to describe what *precision agriculture* is, where this concept came from, and what kind of work it does. This will involve looking at the ways in which *precision agriculture* discursively constitutes a field, within and through which the practical system and technologies it denotes can be constructed and seen as a coherent and meaningful thing, a persuasive and significant rhetorical, commercial, and socio-technical force.

First, I will present some of the core rhetorical and conceptual claims made about precision agriculture and relate these to some of the conventional definitions of this system offered in scholarly, technical, and journalistic texts. This will be followed by a description of the different core technical systems that constitute precision agriculture in general, introduced with historical information about precision agriculture's formation as a field as such.

i. Precision Agriculture discourse: common ground

In the past three years, proposed mergers between six of the world's seven largest agricultural and chemical companies were granted legal permission to proceed by an international collection of states and trade institutions, paving the way for the birth of three new mega-corporations: Bayer-Monsanto, Dow-DuPont, and Syngenta-Chem China (Moldenhauer and Hirtz 2017). With the addition of German company BASF, which received Bayer's seed and herbicide businesses as part of a US Department of Justice antitrust ruling that permits the Bayer-Monsanto merger, these four companies now own a combined 68% of the world market in seeds and herbicides (based on 2015 pre-merger numbers; DeCarlo 2018). Bayer-Monsanto alone will control over a third of the global seed market and one fourth of the herbicide market. Most of the reporting on these mergers has focused on the ostensible economic benefits they offer their respective businesses and industries, also highlighting concerns the mergers create about seed price increases, market competitiveness, and antitrust legislation.

There is a facet of these mergers that deserves closer attention, one useful for reckoning with their possibilities and consequences on a larger, socio-technical scale. Building upon the account of the epistemological and technological transition from broadcasting to precision laid out in Chapter 1, we can consider these mergers as a phenomenon that highlights consequences of this process of the transition from disciplinary regulation of normalized masses or populations, to modular, dividuated, personalized control. Over the previous century, the practice and the industry of conventional farming, especially but not limited to its pursuit in the United States, has been subject to a gradual but increasingly widespread digitization - epistemologically, methodologically, discursively, aesthetically. Put another way, like so many other dimensions of life, conventional farming - *as such* - has been progressively if unevenly reorganized upon the mediated, digital, and cybernetic grounds of *control* over the past century, here intended in the sense defined by Deleuze (1992), Tiqqun (2001), Galloway (2004), Chun (2006), and Franklin (2015), among others. This fact lives at the core of this study, and in many instances informs its attentions and choices of subject. The tools used in the farmer's fields, those found in the farm office for management and organization of operations, and the very objects of farming themselves – land, crops and livestock - were substantially influenced by the adoption of computers, digitized machinery, and telecommunications throughout the 20^{th} century.

Foregrounding this *informatic* history helps throw new problems or historical processes into relief—processes that tend to be obscured or peripheralized in conventional depictions of precision agriculture. For instance, this perspective brings something like the 1980 ruling of *Diamond v. Chakrabarty,* which legalized the patenting of animals and biological processes in general, into focus as a moment of critical importance. Similarly, rather than seeing a series of linear, progressive developments in technology that are then adopted into farming, and that cause certain new problems to suddenly appear, viewing the development of a discourse and practice of "precision agriculture" as catalyzed by the earlier influence of an informatic or cybernetic idiom adopted across the sciences, military, and commercial worlds over the mid-to-late 20^{th} century situates that development in a different—and I argue, more useful—context. It allows one to see how computer-assisted genetic manipulation, for example, has been integral to developing proprietary seed varieties and chemical treatments, which have in turn been instrumental to the rise of global seed and chemical giants in the farming industry like Syngenta and Monsanto. Informatically facilitated inter-operability, so to speak, is what has made such mergers attractive business propositions. It is what created the grounds for recognizing the opportunities for merging such outwardly unrelated businesses and practices *as such*, by situating each component in a milieu in which they became mutually intelligible, recognizable, and relatable.

The process of agricultural digitization has unfolded unevenly across different areas of farming over the past century, and especially the past 40 years. This process may be viewed in terms of unfolding along two general, biological and mechanical lineages (ETC Group 2016). The computerization of agricultural biology involved the recognition and control of genetic matter upon informatic and computational grounds, and the development of information-based tools for biological and genetic management, experimentation, and manipulation of seeds, livestock, pesticides and hormones (Clark 1998; Kloppenburg 2004; Pechlaner 2012). Monsanto's development of proprietary, genetically prepared "RoundUp-ready" hybrid seeds in recent decades is just one particularly famous example of what the move towards digital engineering in farming has engendered on a longer time scale and across many more dimensions of non-human life.

The second general field of agricultural digitization encompasses farm machinery and the insinuation of computerized information technology into farm management, from satellites and tractors, to drones and machine learning algorithms. This is more commonly what *precision agriculture* is used to signify, though it is a core purpose of this study to argue, to the contrary, that both the biological and machinic digitization are closely related if not outright identical, ultimately highlighting different aspects of a more fundamental, common phenomenon. Taken together, these developments suggest that at present, most aspects of conventional farming, from seeds to harvesters to the "supply chain" itself, are increasingly understood through and executed with information, data, and media technologies. Precision agriculture by this definition is generally regarded as having been under *de facto* development since at least the mid-1980s. This early history is relayed below, followed by a description of the most important or common components of the precision agriculture system/concept.

II. Components of Precision Agriculture

It is worth reiterating here that a core contention of this work is that any understanding of precision farming *as such* must not be limited to technologies for crop production, as is often the case. Precision agriculture has not only played a significant role in the industrial production of so-called animal products like flesh, milk, and eggs; by paying attention to the technologies marshaled to govern and control animal lives, bodies, activities, and genetics in the discourse of precision farming, new insights into the birth and the productive effects of this technological system emerge. Yet because the application of *precision* discourse in farming originated in work on industrial commodity crop production, especially grain crops, the following outline will at first emphasize describing technologies developed within and for that context due to their primary and influential effects.

The first efforts to computerize aspects of farming during the 1980s helped to catalyze important foundations for further development in that area, establishing early intellectual communities and outlining future research agendas for digitization and mediation of agriculture.

Specifically, the first-generation technologies described below played an important role in transplanting the epistemology of cybernetics and information theory – as well as the martial 'command and control' doctrines and technologies that developed from these - into farming, influencing how farmers, researchers, politicians, and businesspeople, among others, would begin to understand, organize, and administer agriculture during the 21st century.

i. Technological Origins: space, place, and soil

a. Space: Remote Sensing and Landsat-1

As shown in Chapter 1, the first technological element established in the system now known as precision agriculture was the cybernetically redefined concept of *precision* itself. The most immediate technological and methodological developments in that process resulted from the confluence of two initially separate but equally influential technological systems – satellite-based platforms for remote sensing and navigation beginning in the 1960s, and geographical systems for farm field soil analysis in the 1980s (cf. Mulla 2012).

The use of satellites for agricultural purposes predates the first records of the phrase *precision agriculture* by over a decade, to the launch of the Earth Resources Technology Satellite 1, or Landsat 1, in 1972 (Bauer and Cipra 1973). Landsat 1 grew out of a 1966 proposal by the Department of Interior's (DOI) U.S. Geological Survey agency (USGS) for a remote sensing satellite program, initially inspired by photography gathered during Gemini and Apollo's Cold War "Space Race" missions (Landsat Science 2020). The DOI was joined by the National Aeronautic and Space Administration (NASA) and the U.S. Department of Agriculture (USDA), who coordinated to establish the Earth Resources Survey project (NASA 1998). The aim of the project was to explore and develop technologies and methods for gathering more accurate data on so-called Earth resources from space, including geology, hydrology, geographic information, and critically, crop data (USGS 1976). Designed as a platform for implementing advanced multispectral remote-sensing technology, Landsat 1's agricultural applications included its potential to improve the accuracy of crop production information in the US by analyzing visible light, infrared, and radiometric sensor data to identify agricultural land and generate information about crops and productivity. This survey information on crop types and agricultural landscapes was and remains important for both determining crop production estimates essential to the agricultural commodities markets, and for developing up-to-date, accurate national trade policies (Eisgruber 1972)—an example of the historical connection between markets, data, and information technology that will be covered further in Chapter 3. Landsat 1 was used in this capacity until 1991, when data it had generated served as the foundation for a new way of understanding farm fields: using remote digital sensing not only to take images of ground use and plant prevalence, but also to exploit imaging data in order to estimate more detailed *qualities* of soil and crops, which in turn created the conditions for quickly establishing differences in soil composition properties throughout a field or region (Bhatti et al. 1991). Remote soil sensing for dedicated agricultural purposes only truly began at this point in 1991, when Landsat images were used for the first time to analyze soil properties explicitly for use in farming (Mulla and Khosla 2015).

At the same time Landsat 1 was beginning to transmit its remote sensing data back to earth in the early 1970s, interest in ground-based or proximal sensors for explicitly agricultural purposes had also started to accelerate. Among the earliest research in proximal sensing for agriculture were 1973-4 experiments with adapting sensor technologies using electrical conductivity and resistance, originally developed for the mining industry, for use in testing farmland soil salinity (Parasnis 1973; Halvorson and Rhoades 1974). Commercialized soil sensing technology was first available in the early 1980s, with one pre-GPS assisted device designed to offer on-the-go variations of fertilizer application.

Consequently, electronic and digital sensing systems have a fair claim to the title of at least the earliest technical *precursors* to precision agriculture, insofar as they were critical for putting new information technologies for understanding and approaching farming into practice. But because precision agriculture is partly defined by surveillance and control of phenomena at sub-field and individual scales, Landsat 1's uses for region- or field-scale surveys of agricultural activity fall outside the purview of most conventional classifications of the practice, and early proximal devices lacked the ability to GPS-reference, limiting their accuracy and generation of geo-referenced, intra-field mappable data. Of the few existing accounts of precision agriculture's early history, observers tend to point to President Ronald Reagan's 1983 'declassification' of GPS as the beginning of precision agriculture. As discussed in the previous chapter and below, however, the practicality of GPS for farming was extremely limited until its full declassification in 2000. My research suggests a slightly different origin for precision farming, located not in the advent of electronic and digital sensing in general, or the announcement of the GPS network, but in the publication of a pair of epistemologically novel theories during the 1980s that proposed the use of geographical information systems and sensory media for more accurate and rationalized approaches to soil sampling and treatments. These proposals embodied and advanced a more universal, tectonic reorganization of the grounds of agricultural knowledge upon essentially cybernetic foundations. This quantitative, informatic perspective did not grow from the availability of a given tool like GPS or Landsat 1, but rather made tools like these - digital sensing, computing, telecommunications and visual media - explicitly legible to the context of agriculture; it put them into relation upon the same epistemological tableau where the notion of *precision* made sense.

I argue these influential proposals signaled an important epistemological, even phenomenological evolution in the basis of understanding agriculture, yet one explicitly rooted in much deeper histories of technological innovation within market societies (see Chapter 3 on this point). Their history offers a more useful context for thinking about the origins of precision agriculture, understood as a specific, comprehensible discourse and emergent technological system, than the simple, essentially determinist chronologies of farm equipment one tends to encounter in industry histories of the subject.[8]

b. Soil: Farming by Soil and Site-Specific Management Zones

What made these approaches to soil sampling "new" was their emphasis on finding ways to vary fertilizer applications in relation to differences in soil properties at the sub-field level, something that was theoretically possible to achieve only following the development of computing and sensor technology that was able to detect, classify, and map such variations quickly and at scale.

Soil sampling is the general term for any effort to determine the composition, properties, and fertility of the earth in farm fields, usually to establish the kinds and amounts of treatments to administer so as to maximize soil productivity for a given crop. As noted, the confluence of cheap fertilizers, labor, and mechanization that allowed for increasing field size and farm consolidation during the 20th century led most US farmers to organize their operations at the

[8] In addition to sources like the early Proceedings of the International Conference on Precision Agriculture making this point in prefaces, this understanding was reiterated for me during my observations at the 2018 ISPA keynote speech, where Bayer research scientist Chris Peterson recalled first encountering 'site specific' agricultural practices in the 1980s.

scales of entire fields. Traditionally, the way farmers determined the types and amounts of soil treatments to apply to a given field was to take soil samples more or less randomly in multiple parts of that field, and then average out the differences in soil properties among the samples. With these averages established, the farmer could determine appropriate types and rates of treatments to apply in that field *in general* (Mulla and Khosla 2015). In other words, this method was an inherently normalizing technology that established a mean identity of the soil across individual fields defined as a totality, however varied they were in reality. Moreover, despite academic studies suggesting as early as the 1920s (e.g. Linsley and Bauer 1929) that soil sampling to determine differential rates of application in a field had significant potential, practical means for achieving these ends were hampered by a lack of effective or affordable technology through the end of the century.

By the early 1980s, however, a new crop of agricultural scholars was engaged in efforts to employ emerging forms of information technology to achieving precisely these ends. In so doing, they established the intellectual, technical, and infrastructural conditions for the discursive formulation of *precision agriculture,* which first emerged as a term roughly a decade later.[9] These early efforts initially unfolded within two independent conceptual schools (Mulla 2013). The earlier of the two, the concept of "farming by soil," was first proposed by University of Minnesota agricultural scientist Pierre Robert in his 1982 doctoral dissertation (Robert 1982). Robert is not infrequently referred to as the "father" of precision agriculture in industry and academic literature, owing to his contribution of the theoretical foundations for what became known as precision agriculture, and moreover for helping to establish its first scholarly community, now known as the International Society for Precision Agriculture, in 1992 (Robert

[9] For instance, the ICPA's first conference took place in 1992. The journal *Computers and Electronics in Agriculture*'s first issue was published in 1985.

1982; Larson and Robert 1991). "Farming by soil" proposed collecting and analyzing color infrared aerial photography over time to develop an iteratively more accurate, mappable, and practical picture of farmland properties, toward the ultimate goal of developing a "farm information and management system containing precisely located natural and cultural data [to] improve cost efficiency of future cultural practices" (Robert 1982). In other words, one would gradually collect and refine remote sensing imagery into highly detailed maps of soil properties of a field woven within it, eventually building detailed sub-field images of the various soil traits marbled throughout individual plots. Robert suggested improvements that might derive from using that data included "adjusting seed density, herbicide control, or fertilization in response to detected field problems" over a field (Robert 1982), presaging what is today known as "variable rate" technology.

By contrast, the theory of "soil sampling management zones" (SSM) developed by another Minnesota agricultural scientist, David Mulla, in 1988 (Mulla 1988), proposed using geostatistics and Geographical Information Systems (GIS) data to identify, classify, and map out zones of differential soil properties. These zones would in turn be used to establish fertilizer type and rate recommendations for each distinct zone (Mulla and Khosla 2015). This approach evolved into the notion of "site-specific crop management" mentioned previously. Unlike the concept of farming by soil, site-specific management proposed identifying and delineating individual, homogeneous zones within fields, characterized by roughly equivalent or uniform properties within each zone. The idea was that a more schematic, abstracted, and gradated system would translate into treatments with less extreme and potentially inefficient variability than the overwhelmingly precise approach to soil variations proposed in Robert's farming-by-soil model, while still building a much more localized and specific scale for intervention than uniform treatments of entire fields. Site-specific crop management emerged as the dominant approach in precision agriculture following its adoption and practice over the 1990s and 2000s; many of its fundamental tenets remain visible in the design and programming of contemporary software and sensor systems offered today (e.g. Climate Corporation's "Climate FieldView," which uses zone-scale for historical analysis of various data points - more on these platforms below) (Lowenberg-DeBoer and Erickson 2019). Yet, theories of both SSM and farming-by-soil were integral to catalyzing a group of US-based academics to convene around pursuing the ideas of "variable rate" technologies for "precise" applications of farm inputs over the 1990s, leading to the establishment of the first International Precision Agriculture Conference in 1992, and later the International Society for Precision Agriculture, the most prominent organization devoted to the study and advancement of precision agriculture over the past 30 years. Common to both of these concepts was an emphasis on *place*, evident in the importance of geography, sites, zones, and locations they share. It is unsurprising, therefore, that the next step towards implementing this system involved finding consistent means for accurately mapping and navigating specific agricultural geographies.

c. Place: Global Positioning System

Sensor-based analytics and the organization of management zones represent the foundations upon which many, if not all, core technologies and systems characteristic of precision agriculture are built. Yet none of these would be effectively possible in their current forms without the introduction of another key satellite-based technology to agriculture, the Global Positioning System (GPS). As noted, many sources date the birth of precision agriculture to the declassification of the Global Positioning System for civilian use, and the subsequent development of farm-specific GPS guidance systems in the early 1990s (e.g. National Research Council 1997; Lowenberg-DeBoer 2015). While I disagree with this more technologically deterministic picture of precision agriculture's emergence, its frequency is understandable given the fundamental role GPS has played in actually implementing the recommendations, techniques and possibilities for efficiently and precisely treating land, crops, and livestock first proposed in the 1980s.

The modern GPS system was the product of a 1973 Department of Defense initiative to combine elements of several mutually incompatible satellite navigation systems developed over the 1960s into a single, uniform platform providing globally available radionavigation to the military (Pace et. al. 1995, 238-241). Both these earlier systems and the GPS concept itself were dedicated to essentially two purposes: providing exact locational information to military command and control centers to support and inform tactical operations, and for generating information to guide "precision munitions" to target (Watts 2013; King 2014). GPS is essentially a synthesis of satellite, computing, and radio technology that uses a network of satellites in permanent orbit around the earth as reference points for radio waves. The satellites broadcast a radio signal detected by ground receivers and in tandem calculate the precise location of the receiver relative to four or more satellites at a time, allowing a determination of position across four dimensions: latitude, longitude, height, and time.

GPS thus affords one of the core capacities for "precision" in precision agriculture: highly accurate locational information available in real-time[10]. Initially a classified military technology, GPS was gradually made available to the public beginning in 1983. The system was first used in its intended military role during the Persian Gulf war of 1991, in support of

[10] It is noteworthy that the language of *precision* did not become popular, and certainly not dominant, as a referent for information technologies in farming until GPS was integrated into this system during the 1990s.

precision weapons guidance and logistical command and control (Pace et al. 1995, 1, 245). The complete satellite system was not in place until 1993, however, and several aspects of the GPS technological suite continued to be added to or developed over the coming decades. Initially, for instance, the DoD made publicly available GPS signals deliberately less accurate than their military counterparts, a defense measure that restricted initial commercial uptake of GPS until full navigational capabilities were made available to private industry in 2000 (Lowenberg-Deboer and Erickson 2019, 1554). Yet agricultural scholars had already started detailing the possibilities highly accurate navigation systems might offer farming by the late 1980s (Larsen et al. 1988).

Among the first and most enduring commercial uses of GPS was the locating and tracking of farm equipment. A decade prior to the widespread appearance of commercial automobile GPS units in the late 1990s and early 2000s for road navigation, researchers and farmers had developed and implemented methods and systems for GPS in farming towards two separate but related purposes (Larsen, Tyler, and Nielsen 1988; Colvin, Ambuel and Jeyapalan 1993). On one hand, GPS could be used for navigation and guidance, and in turn, as a foundation for machine automation. While over the 20th century a variety of technologically-assisted agricultural navigation systems had been devised – or at least theorized – prior to the advent of GPS, many were unreliable or practically infeasible (Mulla and Khosla 2015, 8). What GPS offered that earlier systems did not were consistent, reliable, high degrees of navigational accuracy. By combining GPS-mapped coordinates of a given field with routing programs, GPS-equipped farm machinery could be directed within that field along exact routes that would, ideally, minimize the amount of overlap across rows, thus saving time, driver fatigue, fuel, and inputs. On the other, GPS could be used to facilitate the mapping of properties of a harvest, known as yield mapping, described in greater detail in the next section. In short, a combine that is equipped with sensors to measure a harvest could cross-reference the GIS yield data they produced with field locations recorded by the combine's GPS system. This data could then be downloaded from the combine, processed, and expressed as a "yield map," a visual representation of the differences in yield amounts across a field. Collecting data over several years in this way, an increasingly fine-grained picture of variations in productivity could theoretically be developed, which may then have been used to inform planting and treatment "management prescriptions," in the language of a John Deere equipment dealer with whom I spoke in 2017.

In sum, the precision agriculture concept emerged from an assemblage of information machines, communications media, and aerospace technologies that were themselves each derived from efforts to develop more powerful, more accurate, and more informed governance of operations and knowledge of space and place using information technology. As scholars including Caren Kaplan (2018; 2007), Peter Galison (1994), Jennifer Light (2004), Joy Rodhe (2013), and others have shown, such cybernetic command and control technologies most immediately descend from a long and branching tree of antecedent devices and techniques originally designed for facilitating warfare and the administration of empires, kingdoms, and states. And while GPS is undoubtedly an aerospace innovation that grew out of a desire to make missiles, bombs, and artillery more accurate as noted in Chapter 1, it is even more fundamentally grounded in and dependent upon one of the fundamental logistical, rationalizing technologies devised for enabling European imperialisms and settler-colonialisms: the geo-navigational systems of latitude and longitude themselves. These systems, originally devised to facilitate European imperial and mercantile activities during the so-called Age of Exploration were eventually transformed into a uniform global standard at the 1884 International Meridian Conference. In a very real and material sense, the most critical epistemological and technological foundations of precision agriculture are rooted in centuries of developments in communications media and information management systems of control. Such standards, techniques and tools were designed to afford states, militaries, and merchants more accurate, reliable, and rational means for administering empires and cultivating global networks of a nascent capitalist market system. The contemporary, conventional farm field is, in a very literal sense, treated, arranged, and managed through logics of governmentality and martial command and control apparatuses as much as the productivist rationalizations of global capital and the political-economic market system. Its predecessors are battle-fields and colonial topographies as much as factories. This aspect of precision farming's indebtedness to capitalism and logics of government and military will be illustrated further, below, and developed historically in the following chapter.

ii. Guidance & Control, Sensing & Monitoring, and Platforms & Data

The notion of creating carefully mapped management zones within a given farm field, in order to establish parameters for differential treatment, suggested that technologies for practically executing those treatments were necessary. As the first uses of GIS and GPS in crop farming were established, agricultural engineers took steps to practically exploit the potential efficiencies such mapping and navigation assistance technologies made possible (Colvin, Ambuel and Jeyapalan 1993). Depending on their location, conventional US farmers at times must traverse enormous fields often totally bereft of orienting landmarks, as in the flat and dry Plains regions. By contrast, farming in hilly, forested, and water-abundant areas such as those in the northeastern or northwestern United States creates its own challenges for navigating small, irregular fields without constantly overlapping or missing rows. Theoretically, a precision agriculture approach could solve both of these problems confronting conventional, mechanized, monocropping agriculture. Relatedly, developing devices for applying varying amounts of inputs in real time, whether seeds, fertilizers, water or pesticides, would be critical for actually realizing the promise of farming by management zone. Finally, whether dealing with crops, soil, or livestock, the ability to accurately and regularly detect and measure specific conditions and qualities of land, crops, machinery, and environments would be critical for informing treatment and management decisions, that themselves would simultaneously rely on and shape the use of satellite navigation and variable treatment systems. Accordingly, new types and uses of sensing technology were integral to realizing the purposes inherent in precision agriculture.

If GPS, GIS, remote sensing via satellite imaging, and the theories of soil-specific management zones represent the technological bedrock of precision agriculture, then navigation, application, and refined sensor technologies represent the advent of precision agriculture technologies *as such*, iterated upon that stratum. I have organized the following discussion these technologies into three roughly chronologically-ordered core categories: precision agriculture technologies used for guidance and sensing; for application and harvest; and for data and surveillance. Taken together, these represent the general core of contemporary precision agriculture systems as applied to field cropping.

d. Guidance and Control: Lightbar, Autosteer, RTK, VRT

Guidance technologies were among the first forms of precision agriculture introduced into the general agricultural market (Auernhammer et al. 1994; Larson, Nielsen and Tyler 1994). They are also among the most widely adopted and enduringly popular precision agriculture technologies.[11] Comparatively high adoption of guidance technology is a consequence of two factors: 1. navigational and driving assistance derived from GPS are useful to conventional farmers in and of themselves, regardless of any other precision technology, and 2. GPS guidance is critical to the use of several other core technologies in precision farming (Schimmelpfennig 2017). GPS-assisted navigation systems basically allow farmers to keep their equipment running straight down a field, to keep them from overlapping rows, and to increase the accuracy in turns and routes. They range in technical complexity and cost, and generally fall into two categories: lightbars and autosteer. Lightbar systems are a type of GPS-assisted manual navigation tool, where a display unit, mounted in front of the steering wheel, provides the driver feedback on whether or not they are deviating from a plotted, GPS-referenced route. These are usually cheaper, simpler technologies than autosteer, and were among the earliest forms of GPS navigation introduced in farming beginning in the late 1990s (Lowenberg-Deboer and Erickson 2019).

Autosteer, the generic term for commonly used precision agriculture guidance systems (Schimmelpfennig 2016), is a computerized driving automation technology. Like lightbar, autosteer works by following routes programmed into on-board computer equipment. The key difference is that where lightbar systems are usually meant to assist with manual steering, autosteer technology is integrated into the actual machinery of the tractor and assists with or drives the tractor itself. Using GPS and GIS location information, autosteer systems follow pre-

[11] While there are no overall usage statistics on precision agriculture collected by the USDA, according to the most recently available Agricultural Census data on specific crop types, just under half (45%) of farmers growing corn or soybeans in the U.S. use GPS guidance systems, second only to yield monitors in farmer adoption, and significantly higher than other types of precision agriculture technology. Corn and soybeans are two of the most commonly planted and economically significant US row crops (which taken together represent nearly a third of all agricultural land use (~150,000,000 acres out of ~396,000,000), and are therefore a useful, if very rough, baseline for such usage overall (USDA NASS 2019).

plotted routes or maps uploaded into on-board tractor software for a given task, allowing farmers to guide their vehicles with minimal to no actual driving. Lightbar and autosteer technology only became widely popular after full GPS capabilities were made available to the public in 2000, increasing the accuracy of steering down from potentially yards to inches, or less. To achieve the highest degrees of accuracy, on-board navigational systems like autosteer are often augmented with Real Time Kinesis (RTK) stations: satellite-linked relay boxes that can increase GPS guidance accuracy to sub-centimeter degrees (van Es et al. 2016; 7).

Guidance systems like lightbar and autosteer helped create the conditions for more granular control of machinery and crops within a field along two axes. The first involves the most obvious abilities guidance systems offer - finer, more accurate, and more consistent controls over the activities of your tractor or combine, and consequently, the potential for greater regularity and efficiency among drivers and machine operators. The second relates to the opportunities that greater control they create, namely for turning seeders, sprayers, and other application machinery on and off in relation to their position in a field. This is known as "row control," "section control," or "nozzle control," parts of a wider family of application devices called "variable rate technologies" (VRT). When I spoke with North Dakota State Agricultural Machine Systems Specialist John Nowatzki about the history of precision agriculture adoption in US farming, he explained that at least in the Plains region of the US, GPS made VRT like row control much more attractive, and consequently that and other VRT tended to be the next major type of precision agriculture technology adopted following guidance devices.

e. Section Control and Variable Rate Technology

Section control and VRT are tools designed to concretize and mechanically implement the vision of tailored, individualized sub-field controls inherent in the precision agriculture concept. While section/row control and VRT are arguably different types of technology (due to the similarity in the abilities they offer and the ways they operate), I am including them as two lineages of the same technological genus, which outside of defining both here I will refer to generally as "VRT" elsewhere in this dissertation. Section/row control devices, like VRT, are an assemblage of computational, sensory, and mechanical technologies designed to turn a sprayer or seeder on and off as it passes over parts of a field needing treatment, areas that have been deemed out-of-bounds for treatment (the field edge), or areas that have already been treated, as tracked by the GPS-referenced on-board computer controlling the equipment. Row, section, or nozzle control all share and operate using essentially the same basic principle: a given input device, whether a seeder, a sprayer, an irrigator etc., turns on or off at different points depending on its GPS-referenced location in a field. To picture this in a simple way, imagine running your hand down along the length of an older-style lawn sprinkler, the kind that's essentially a tube with holes punched along it at regular intervals. As your hand travels over the jets of water, it plugs the water nozzles, creating a break in the sprinkler pattern that moves with your hand. Now imagine the sprinkler were a seeder, and your hand was an already-planted row. If, for example, you are a farmer driving some form of self-propelled farm equipment over a field and you find you must turn around, cut across a planted section, or have mistakenly overlapped an already-planted row, section control uses GPS-referenced location data and on-board computing machinery to shut the seeder off, ideally preventing over or under-use of inputs.

On the other hand, VRT technically refers to technology integrated into various types of farm machinery (i.e seeders, sprayers, irrigators) that provide control over *rates* of inputs. It allows farmers the physical means to vary the application of various agricultural inputs in real time, alter the seeding rates when planting crops - planting densely or more sparsely - changing the amount of water needed in different areas, or varying the amount of pesticides applied as a seeder or sprayer moves over a field (Grisso, Alley and Thomason 2011). These devices depend upon and work in concert with GPS guidance, mapping/GIS technologies, and can use data gleaned from sources like yield maps and multi-spectral imaging (discussed in the following section) for translating insights generated by soil or yield data into practical plans or treatments.

Using the example of a planter, Nowatzki explained why this technology was comparatively quickly and widely adopted after the adaptation of GPS to farming; in his perspective, it was because

> …the payback is easy to calculate. If you have a field that's not rectangular and you have to go around low spots, or water areas, or trees, or wind turbines or whatever, and you change the shape of that field so you run across rows diagonally from the previous one, so then you turn off row by row [when overlapping previously treated rows]. So farmers - you know, they're spending $100 an acre for seed, for corn for example, or even more than that for sugar beets - can quickly do the math. If they've got a hundred-acre field, they can avoid overlap over two acres over the whole field - that's 200 dollars. And if they've got thousands of acres, that adds up quickly. (Nowatzki 2018)

In sum, VRT/section control, particularly early and less sophisticated forms of section and row control than those based on mapping and data technology mentioned below, were essentially the next major group of precision agriculture technologies to be adopted, partly because VRT integrated so well with GPS-based guidance systems many already owned, as well as because it works more or less automatically, so that its benefits were relatively clear.

Finally, another application technology of a somewhat different genre than those mobile devices described above bears inclusion here as well: mechanical irrigation systems, especially those used in the arid High Plains region of the American West.[12] Like tractors and livestock, modern irrigation technology is also the object of efforts to digitize and mediate their operations. Irrigation is an interesting case in the context of precision agriculture, because given the variety of types, purposes, and contexts of irrigation systems, a wide array of precision agriculture techniques and technologies can be applied to their operation. Automatic shut-off, section control, digital sensors generating real-time water usage or environmental data and other variable-rate digital-mechanical methods in center-pivot irrigation systems are one example; wireless moisture sensors, integrated into sprinkler or drip irrigation systems mentioned in the section on sensors below, constitute another. Center-pivot irrigation technologies generally consist of a central mounting and pivot point, and a series of segmented pipes stemming from the center, mounted on wheels. At the central point, engines pivot the pipe-arm and

"Crop Circles in Kansas," an overhead image of center-pivot irrigation. (NASA Earth Observatory 2005)

[12] This region, roughly speaking, constitutes the lands around and east of the Rocky Mountains (and in some areas, the coastal and rainforest ecosystems of California and the Pacific Northwest), and west of the states whose eastern borders run along the Missouri-Mississippi river systems: essentially the North-South axis of states from Minnesota to Mississippi. See Dieter et al., 2018, "Estimated use of water in the United States in 2015," *U.S. Geological Survey Circular* 1441, 65 p., https://doi.org/10.3133/cir1441.

pump water out to its sprinklers, which are rotated about the field in a circle as they water crops and soil. A very popular form of irrigation, center-pivot technology was first introduced in the 1950s. It was designed to make traditionally dry, flat areas of the US high plains regions viable for rationalized and intensive factory farming, by allowing farmers to quickly and efficiently irrigate large amounts of otherwise dry land (Anderson 2018).

If you've ever had a chance to fly from one coast of the United States to the other, it is hard to miss the quilt of perfect green circles that seem to stretch to infinity west of the Mississippi. Center pivot irrigated farms dominate the landscape of these dry, flat areas, a material embodiment of a very specific political-historical legacy: the deliberate, systematic, and violent appropriation of the plains and prairies from the native peoples who called them their home by the settler-colonialist United States. This land was first made available to U.S. farmers as a part of American colonization efforts in its western territories over the course of the 19th to the early 20th century: warfare, extermination, expulsion, and the resettlement of Native American peoples cleared the territory for settler-colonials, and annexation into the political and economic sovereignty of the United States. This process in turn opened that region to integration into the system of production agriculture of monocropped commodities on an industrial scale. Growing major commoditized plants like maize and soy, however, alien in their contemporary form to the ecological and climatological prairie conditions of the arid plains, demanded significant re-engineering of the soil, biome, and intensive application of artificial inputs, including water. This was especially true when these crops were grown using the intensive, industrially-rationalized methods American settler-farmers adopted or were compelled to adopt from the 1910s and 20s on (Fitzgerald 2003; see Chapters 1 and 3 for more on this history). Center-pivot and related forms of mechanized irrigation were designed to resolve that issue, and they have helped to almost completely transformed that region from diverse semi-arid prairie ecologies into one of the most ecologically uniform, productive, and economically important agricultural regions in the world,

Consequently, settlement and re-engineering of the West by the plows that broke the plains have also been a major driver of the reduction, eradication, or displacement of entire ecologies and non-human species inextricably entangled with that of Western native peoples – namely the indigenous flora and fauna of the vastly shrunken prairie environment. Further, irrigation for production agriculture has put serious strains on the riparian ecosystems and water resources of the drought-prone West, and many have consequently become dependent on water drawn from underground "fossil water" – ancient water reserves that constitute the major aquifers of the plains and western regions – in a non-renewable process that is effectively a type of mining. Decades of irrigation have threatened to irreversibly deplete water reserves in the Plains, further degrading the environmental and ecological health of that enormous region. Ironically, recent research and development of "precision" techniques and "smart" farming for irrigation and moisture monitoring systems have been pursued and presented by industry and production agriculture proponents as an efficiency-generating solution to the very harms they have helped produce, aimed ultimately at an effort to maintain the political-economic order embodied in conventional agriculture that motivated the adoption and use of colonialist terraforming technologies like center-pivot systems in the first place (e.g. Dorsey 2017).

This dynamic - conventional, industrial agriculture produces environmental and political problems that beget disruptive, technical 'solutions' born of digital capitalist discourse - is evident across the technologies, activities, and discourses that constitute precision agriculture as a socio-technical assemblage. This tendency was outlined in the introduction, and more examples of are offered below in the course of contextualizing the development or uses of other major precision agriculture technologies, such as the adaptation of sensing technology to farming described in the next section. But these historical, techno-political dimensions of precision agriculture are the chief focus of Chapter 3, and a more detailed and thorough discussion of that topic can be found there.

iii. Sensing and Monitoring: proximal and remote sensing; yield monitors

Precision agriculture grew from an engineer-like vision for improving conventional farming, innovating into it greater efficiencies by more closely classifying, mapping, and measuring the earth, more effectively bending it to the needs of rationalized commodity production. Since Landsat 1 transmitted its first images, many further innovations in measuring, monitoring, and treating the earth have emerged and been adapted for farming, technologies that now constitute what I see as the second major family of precision agriculture technologies: sensing and monitoring media. These assume myriad shapes and include many forms of sensory machines, here defined as technologies for detecting and measuring biological, climatological, electromagnetic (EM), and other phenomena as they interact with or speak about the properties of some form of matter, whether inorganic, plant, or animal. Sensory equipment generally falls out along two lines: "proximal" sensing that occurs near-to or in the ground itself; and "remote" or "distal" sensing, often mounted on air and spacecraft. Remote sensing is commonly accomplished using satellites, planes, and drones; proximal sensing, through handheld, fixed, or machine-mounted (i.e., tractors) sensors. This section will begin by defining remote and proximal sensing, explaining some of the core properties and uses of both before turning to consider soil sensing, the earliest form of sensing in agriculture, as an example. I will then proceed to describe and consider other types and roles of proximal and remote sensing in farming today. Finally, this section will close by looking at another type of sensory technology: yield monitors, an important source of data used in a variety of agricultural and market applications covered in the next section on Platforms and Data.

f. Remote Sensing

Remote sensing in agriculture, particularly industrial row-crop farming, usually involves the use of some type of electromagnetic (EM) reflectance measurement from the air and has seen dramatic technological and commercial developments since the initial uses of satellites like Landsat-1. Remote sensing represents one the most significant and expanding technological dimensions of precision farming today, particularly with the advent of drone and other potential robotic platforms specialized for agricultural uses, discussed in this and in the following sections.

Satellites, the first major remote sensing platforms in agriculture to rely on digital, non-analog visual technologies (e.g. human sight, aerial photography), have seen significant improvements over the past three decades. Greater image resolution, spectral capture, bandwidth availability, and faster "return rates"– how frequently a satellite can pass over the same area and return updated data - have (Mulla 2011). The U.S. government has introduced several satellite-based remote sensing systems since the late 1980s, including a wide range of publicly available NASA imaging data from the Earth Observing Satellite (EOS) program. In 1992, the Land Remote Sensing Policy Act permitted private satellite imaging, opening a way for a number of commercial satellite-based remote sensing platforms over the years (e.g. the RapidEye system, now owned by California-based commercial satellite company Planet Labs). While both public and private systems have multiple applications outside of farming, they have been a hallmark of precision agriculture since its inception, offering variable resolutions across visible spectrum, Normalized Difference Vegetation Index (NDVI), thermal, infrared and near-infrared, among others.

Satellites, however, have several distinct disadvantages for farmers interested in remote sensing. Most significantly, satellite imaging is only viable on cloudless days. Satellite imaging is also subject to a number of distorting effects, from the angle of the sensor in relation to earth, to atmospheric interference, to changing light conditions over time, limiting the period when seemingly undistorted data is available for capture. Satellite data can also require significant processing before it becomes useful to a farmer (Yao et al. 2011).

Lower-altitude aircraft, when equipped with the appropriate sensors, processing algorithms, and associated software suites, can mitigate many of these limitations. The use of piloted aircraft in farming has a long history, but planes and helicopters have been predominately used for crop dusting and other input applications or overhead visual inspection. Piloted aircraft have seen relatively scant use for remote sensing over the 20th and 21st centuries (USDA ARS 2005; Thomson et al. 2004). One major change in remote sensing for agriculture has taken place relatively recently, through the adaptation of remotely piloted aircraft, also known as "drones" or "Unmanned Aerial Systems/Vehicles" (UAS/UAV), to farming. Based on my observations of farmer, press, and industry attention, this has been one of the most significant overall developments in precision agriculture over the last decade, though as drone industry employees and various farmers I interviewed have highlighted, actual adoption and delivery on hype have yet to pan out. Although drone use in farming is not nearly as well-established as GPS navigation or yield monitoring, it is clearly a factor of growing economic and socio-technical significance among farmers.

Contemporary remote sensing systems offer a wide variety of capabilities, including measuring crop yield, biomass, and density; monitoring crop health - e.g. water stress, diseases, insect and other “pest” activity; and detecting weed types, distributions, and prevalence. This data is generated using a wide and growing variety of cameras and EM sensors. The most common include Red-Green-Blue (RGB), Near Infrared (NIR), multispectral, hyperspectral, thermal, Light Detection and Ranging (LIDAR), fluorescence, and conventional photographic devices.

Permutations of RGB and NIR sensing are particularly common, especially when used to generate NDVI images, a type of visualization that expresses differences in EM reflectivity. RGB, NIR, and multispectral (combining RGB & near infrared) sensors measure “broadbands” of EM radiation absorption and reflectance rates over the RGB and near-infrared spectra in plant matter. Plants absorb high amounts of radiation in the visible spectrum, from 400-700nm, especially in the lower blue and higher red ranges, resulting in the strong green color associated with most plant life (Mulla 2012). At the same time, plants reflect high amounts of near infrared radiation (700-1300nm), and the more leaves a plant has, the higher the reflectance rate (Mulla 2012). Multispectral sensors capture data registering differences between the reflection and absorption rates, which can be translated into NVDI images. NDVI images are used to map, measure, and visualize certain crop properties (Schmidt et al. 2009), including the greenness of plants, a metric of health, crop biomass, nutrient deficiencies, and the spatial distribution of plant matter, which in turn can inform crop treatments, or be translated into yield estimates (Mulla 2012). While NVDI is a very common type of remote sensing visualization in precision agriculture, the information that can be gleaned from that method has significant limitations; soil reflectance can affect its accuracy, and it is restricted in terms of the kind of crops to which it is applicable (Souza, Scharf, and Sudduth 2010).

Consequently, researchers have made efforts to develop more accurate and reliable alternative indices and sensory technologies over the past two decades. Hyperspectral sensors, for example, offer a different option for measuring a variety of EMS reflection and absorption phenomena in plants. In contrast to multispectral/RBG imaging, which detects radiation in ~50nm "broadband" groups of red, green, blue, and near infrared spectra, hyperspectral imaging is a "narrowband" technology that samples at multiple small frequencies (10nm) across the entire visible and near infrared spectrum (Mulla 2012). This type of imaging offers the ability to measure very specific plant traits at more granular scales and with greater accuracy that are unavailable to multispectral imaging, including crop chlorophyll content, disease indicators, pest activity, or nitrogen levels over time, but is costlier in terms of technological complexity, processing time, and financial expense. Fluorescence sensors offer similar possibilities to multi- and hyperspectral sensing, using an alternative method for generating EMS information on crops.

LIDAR, by contrast, is a spatial surveillance technology that offers the ability to generate highly accurate maps and geographical information using light reflection, akin to the principles behind RADAR and SONAR. In farming, LIDAR is used for topographic mapping and biometric identification of plant and animal species. LIDAR maps can help establish topography-dependent light patterns in a field, as well as guide machinery through areas with poor GPS reception, such as under the canopies of orchards. It can detect and monitor insect types and activity with apparently extremely high degrees of accuracy, which in turn can inform pesticide applications and other so-called "conventional" treatments (Mulla 2012).

Proximal sensors can be used for the same purposes as remote sensing, employing EM reflectance of the varieties listed above to generate information about crops and soil. They also offer opportunities for data collection that is less easy to gather through remote sensing, particularly real-time information about organic, inorganic, and environmental properties at extremely local levels – e.g. atmospheric moisture levels in multiple locations in a field or orchard, information about underground conditions, or information about soil or crops used in VRT.

g. <u>Proximal Sensing</u>

Proximal sensing is performed in a number of ways: by hand, through sensors mounted on ground machines like tractors, combines, and sprayers, or with static types of sensors like ground spikes or moisture monitors. Depending on the device or application, proximal sensing can involve optical EM sensors like those used in remote sensing, or a number of other technologies less common or feasible in remote sensing: electrochemical, electromagnetic induction, and radiometric sensors, ion sensors, or even ground penetrating radar. Data from these sensors is used to inform things like fertilization, pesticide, or irrigation choices.

Precision agriculture proponents point out that proximal sensing shares many advantages with remote sensing, namely, the ability to create multiple types of information faster, and more accurately than most humans could accomplish in-person. Human farmers, the argument goes, need time and lots of experience to learn how to recognize important but small differences in plant appearances or states, properties computers and digital sensors can register and identify immediately, accurately, and without bias (Mulla and Khosla 2015).[13] Hand-held equipment, for

[13] Consider: "Human eyes are in fact a pair of reflectance-based optical sensors. However, human eyes require experience to discern subtle differences in crop appearance due to various biotic and abiotic stresses. Machine-

instance, can be used to scan plants for identifying floral biometrics, detecting environmental stresses or indicators of bacterial or insect damage. Soil spikes and other statically located sensors offer round-the-clock networked monitoring of conditions in a given area, like a vineyard or a section of field.

Among the earliest forms of proximal sensing - and of precision technology in general - were those used for generating data about soil. As we saw earlier, grid-mapping soil samples in individual fields and translating the results into GIS data was something of an analog computational precursor to precision agriculture-proper and was the foundation for “site-specific” and “farming by soil” approaches underpinning the later IT-based precision concept. Soil sensing is used for many of the same purposes as physical, chemical soil sampling: to identify and measure the many and complex soil qualities important to crop productivity, like the soil pH, salinity, ratios of organic to inorganic matter in soil, clay content, moisture levels, soil types, and other nutrient and mineral contents, and soil microbiomes, among others. Physical soil sampling - hand-collecting and then testing the chemical properties of soil drawn from different parts of a field - was and remains an important form of soil sampling in its own right, as well as for so-called “ground truthing” (comparing mediated sensory data with rigorous physical measurements) digital soil assessments today. Unlike traditional chemical testing of physical soil samples, however, digital soil sensing technology, whether proximal or remote, is intended to offer a more granular and modulating picture of the qualities of a field’s soil without the need to regularly, physically test different sections of a field. Relatedly, digital soil sensing’s fast and real-time data are translatable as feedback for, say, VRT machinery for varying treatment rates of pesticides or fertilizers, giving digital sensing an ostensibly actionable utility and control

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based optical sensors, on the other hand, can be used repeatedly without bias or need for experience” (Mulla and Khosla 2015, 18). Consider also: zoom zoom zoom boom, Big Data.

heretofore unavailable to industrial farmers. Another, more recent variety of proximal soil sensing uses what might best be characterized as an internet-of-things approach, employing wirelessly mediated in-situ sensors designed to give live feedback on the conditions of a farm (Ferrández-Pastor et al. 2018). Sensors like these often take the form of spikes driven into the ground, or poles staked throughout a field. These can, for instance, send live feedback to automated irrigation systems about current soil, crop, and atmospheric conditions, directing when, where, and how much to water. Paired with GNSS, VRT, and machine learning algorithms, proximal sensing data can be used for real-time application of pesticides or fertilizers based on sensor feedback as a tractor moves through a field. Sensor data gleaned from vehicles can, like remote sensing data, be used create maps of specific sub-field properties, i.e. clay content or moisture distribution in the soil.

Outside of strictly agronomic sensing, agricultural telematics and labor surveillance technologies are becoming increasingly common and significant. Telematics is a portmanteau of *informatic* and *telecommunications*, and broadly signifies technologies used for the "transmission of information, especially (in later use) for the purpose of monitoring, automating, or controlling certain processes" (OED 2020). Today, *telematics* usually connotes generating and transmitting data about motor vehicles and their operation specifically. Companies like UPS, for example, have famously pioneered the practical use of telematics by outfitting delivery trucks with scores of proximal sensors that measure machine and worker activities in surprising detail, including not only things like engine performance, but more importantly phenomena like how often a worker used the brake - or simply had their foot on it - how many times they backed up, turned left, idled, opened the back door, put their seatbelt on and off, took the fastest/assigned route, and more. In my research, such fine-grained telematics had yet to see widespread implementation in much farm equipment, but there have been clear and unmistakable strides in the direction of achieving increasingly detailed and omnipresent worker surveillance. It is already standard for many machine-mounted precision agriculture platforms to offer machine data that can be tied to specific worker IDs, giving employers the ability to monitor workers from afar, gathering information about how long it took worker A vs. worker B to plant 100 acres, information that can and is used to measure and compare different worker's productivity or efficiency rates as they plant fields or spray fertilizer.

Outside of the combine or the grain truck, workers are increasingly tracked through sensors and cameras in farm buildings or property, or on smart phones and similar handheld devices. These are in many instances put to fairly conventional and now relatively common uses, e.g. as digital punch-clocks (e.g. Trimble's Ag Time Tracker; more on this in Chapter 4, see also Gilmore 2018 and Levy 2015). Yet, haptic and mobile media technologies are also being expanded to offer more minute and comprehensive surveillance data on workers, as they pick strawberries, milk cows, or prune trees - measuring how many steps they take down a row, how long they move from animal to animal, or marking potential moments of "stolen time" in capitalist parlance. In short, telematics and digital worker surveillance systems are proximal sensing technologies put towards the same age-old, classically Taylorist ends of tracking and control that information systems from punchcards to worker IDs always have: only now, they increasingly afford significantly more granular, far more omnipresent digital-Taylorist capabilities to the owners and managerial classes of the 21st century.

h. Yield Monitors

If the hope expressed by the notion of "site-specific management zones" is a way to translate a clearer understanding of differences in productivity rates *within* a field into a workable system, one needs two kinds of tools to both recognize those differences and implement differential treatments accordingly. The latter fall under the mantle of VRT; the former, under yield monitors and mapping. Yield monitors are essentially sensor and software systems that work in tandem with GPS and GIS to register and record the properties of a harvest; they measure and record yield amounts and a variety of potential crop qualities as those crops are harvested. Cross-referenced with specific harvest site location data, yield monitor data can be used to visualize those differences with yield mapping software, offering a picture of the differential rates of productivity in a given field down to variances in things like protein or moisture content from one row to the next (Thylen and Murphy 1996: 271-272; Grisso, Alley and McClellan 2005). Judged by adoption rates, yield monitors are very useful to grain farmers: the USDA's 2012 Agricultural Resource Management Survey reported that 73% of corn and soybean acres were farmed with some type of precision agriculture practice, with over 62% of corn and soybean farmers using yield monitors (USDA ERS 2019).

"Yield" is the general term for describing the amount of agricultural productivity of a crop harvest in relation to area of land, usually by volume (i.e. by "bushels" for grain in the US). Yield plays a multifaceted and major role in conventional market-based agriculture. Yield estimates based on previous year's harvests and weather conditions are used to establish a baseline for expected yield at harvest, called "target" or "potential" yields, which are themselves used to set insurance rates, establish the pricing of agricultural futures contracts, and provide governments with food production projections for the year (Ittersum and Rabbinge 1997). Information about crop planting rates and estimated yields influences the prices of farm goods as commodities, which in turn establish what a farmer can expect to earn from their overall harvest. Yield information also shapes farmer's decisions about what and how much of a crop to plant, as several years of poor yields/financial returns can cause farmers to plant different crops; in aggregate, those changes can create boom or bust cycles in crop prices and in the financial stability of farms writ large. Given the financial and managerial importance of yield to a farm, clearly understanding how much a farmer expects to or actually harvests, and also determining how to best ensure optimal returns by maximizing crop productivity, is critical to the business of conventional farming.

Prior to combine-mounted yield monitors, the most common ways to calculate one's yield involved averaging physical samples of crop yields from different areas of a field - not unlike the traditional method for determining the average properties of a given field's soil. That method might offer an accurate idea of the overall yield of a given field in total, but it does not offer a picture of sub-field variations in yield. Such a picture would allow a farmer to fine-tune their fertilizer application in specific areas or determine how densely or sparsely to plant their crops in relation to the changing characteristics over a field.

The disconnect between this desire and the material realities of so-called conventional farming in the 20th century is in part responsible for the genesis of the precision agriculture concept among agricultural scientists primarily interested in soil fertility. Better understanding the specific properties of a field theoretically translates to a better understanding of how to customize treatments for uniform species of crops across non-uniform fields to maximize their productivity. In short, improving yields usually means increasing returns on investment, offsetting the costs of seeds, fertilizer, soil treatment, pesticides, herbicides, water, machinery, land purchases or rental rates, human labor, and other overheads. In the political-economic context of a rationalized, capitalist, commodities-manufacturing farming system, a farm generally sinks or swims on its return on investment, making this knowledge extremely valuable.

Accordingly, a number of methods for building more precise pictures of grain yields have been developed since the late 1980s. *Yield monitors* are sensors mounted in the internal grain elevator of a combine harvester that measure the rates and properties of grains as they are harvested and drawn through a combine.[14] As Purdue agronomist and precision agriculture expert Bruce Erickson detailed to me, there are several different types of yield monitors, from impact sensors that measure electrical conductivity or volume, to radiometric devices that use gamma radiation to measure flow rates, and yet more varieties for non-grain crops. Many yield monitors can measure crop moisture content, and more recent models can even detect properties like sugar or protein content. Critically, yield monitors can also gather locational information; as a combine passes through a field, the monitor pairs intake rates and properties of a crop to GPS data about exactly where it was harvested.

Location-referenced yield data is used to generate digitized *yield maps*, which display those rates and properties of a harvest through an array of possible media systems. These include real-time representations on cab-mounted displays, apps on tablets or smart phones, and computer-based programs like AgLeader's Spatial Management System. Yield monitoring and mapping are integral to even a relatively simple precision agriculture system, because it is in the mapping and analysis of harvest data that the basic promise of precision agriculture is realized. Depending on the program, yield mapping software can display harvest data as any number of variable layers, reflecting different properties of the harvest captured by a yield monitor. Farmers

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[14] "Combine harvesters," or "combines" more colloquially, are a type of self-propelled farm machinery that literally combine several steps historically involved in harvesting a crop – namely reaping, threshing, and winnowing – into a single, mechanized process.

can then see which parts of their fields were the most productive and in what ways, informing future treatment decisions regarding soil, fertilizers, water, etc. In this way, yield mapping is the crux of developing what one John Deere equipment dealer described to me as the "management plans" farmers develop, outlining how and what to treat and plant in that field in the future.

For example, consider the precision agriculture platform offered by AgLeader, an agricultural technology company formed in 1986 that marketed one of the first widely adopted yield monitors (Lowenberg-Deboer and Erickson 2019). AgLeader sells communications, data analysis, and visualization software, through which a farmer can take a previous year's yield map and overlay it with a soil quality map, in order to determine which areas were more or less productive. Based on that map, one can create planting, spraying, or watering "prescriptions" using programs on a home computer and upload that plan into the appropriate VRT-equipped machine. That equipment, in concert with GPS and autosteer systems, would follow that mapped prescription to treat the field in accord with those variations automatically, customizing the rate or intensity of the application as it traverses the land.

Development of yield monitoring, mapping, variable rate application, and precision irrigation represents one of the chief ways that foundational concepts and technologies of precision agriculture have materialized the goal of practical, agricultural control on a granular, sub-field scale. These technologies and concepts have existed in one form or another since the birth of "site-specific" management and precision agriculture concepts in the late 1980s and 1990s. Indeed, the confluence of geo-referenced soil data and variable rate technology for "precision nutrient management" represented the first truly practical form of precision agriculture technology, reflected in the fact that most studies on the utility and profitability of PA during the 1990s and 2000s focused on this aspect of farming (Lowenberg-DeBoer and Swinton

1997). Since the mid-to-late 2000s, however, a number of additional ICTs for monitoring and analyzing environmental, field, and crop properties have emerged. I have grouped this third core set of precision agriculture devices under the rough designation of "platform and data" technologies and explore them in the following section.

While certainly not intending to offer full account of the surveillance technologies now employed in farming, the sensors described in this section constitute some of the major sensory technologies in agricultural use, historically and at present. In keeping with the origins and original purposes of nearly every technology described in this chapter, sensing technologies writ large are also essentially a collection of military-industrially sourced apparatuses derived from those designed to offer greater battlefield C3I. In other words, digital sensory media like those used today in precision farming were first developed to facilitate government and military capabilities to render otherwise opaque environments and phenomena legible, improving command, control, communication, and information capture in areas and activities both foreign and domestic. As Pamela Mack illustrates in her study of the social construction of the Landsat program, the first true multispectral sensor used in the program – the "multispectral scanner" - was the direct result of a DoD-funded research project dedicated to employing newly-developed satellite technology towards the reconnaissance and surveillance of battlefields (Mack 1990). This project, like so many others, involved a collaboration of civilian, academic, and military researchers (in this instance the DoD, the University of Michigan, and NASA) that embodied "blurring of the distinction between civilian and military problems in an era preparing for total war" common to the origins of so many informatic, computational, media and telecommunications technologies (Mack 1990, 71). The word "hyperspectral" is itself little more than a marketing term coined by the DoD as it worked to make classified sensor technologies commercially available and attractive to private industry in the 1980s (Goetz 2009, S5).

The purpose in highlighting the martial origins of these and the other technologies described in this chapter is not to suggest that there exists some kind of essentializing, overdetermined, tainted 'essence' that inheres within any device ever to derive from or be used for warfare. The intent is rather to trace a common thread connecting each of the core technologies – material and discursive – expressing a fundamental imaginary, a set of desires, visions, and intentions that have informed their socio-technical development, and in turn have lent the assemblage named *precision agriculture* a specific socio-technical character. My aim is to build a history that explicitly grounds precision agriculture within longstanding historical processes, specifically those propelled by capitalist imperatives to grow and innovate in production and efforts to achieve more complete government of worldly phenomena in general, in order to contest the dominant narrative and rhetoric that organizes, supports, and marshals forces towards the normative and conventional understanding of precision agriculture.

iv. Platforms, Media, and Data

All the data gathered from proximal and remote sensing devices would be essentially useless without a significant computational and media infrastructure of hardware, software, interfaces and telecommunications apparatuses to support it. Devices and programs dedicated to transmitting and translating the data manufactured by tractors and drones into human-readable images and text, along with those used to upload operation instructions to farm equipment, are a critical technological genre in the practical application of precision farming, and one growing rapidly in importance. Data processing, digital media and telecommunication systems, and digital platforms therefore represent a final core group of precision agriculture technologies discussed in this section.

i. Platforms

Digital technologies have only grown in importance over the past decade, as computing power has increased, data has become cheaper to manufacture, and developments in data processing and analytics have helped inaugurate something of a second phase in precision agriculture. If the first was focused on integrating geospatial and sensor technologies in machinery, the second has been about increasing the types and volumes of data available from the farm towards a relatively distinct set of uses. As more equipment has been digitized, sensors have proliferated, and more systems have been developed to render elements of flora, fauna, mechanical, behavioral, and environmental phenomena in informatic terms, farm-focused computing startups advertising the power of big data, machine learning, and algorithmic efficiency have bloomed across the industry. Whether created to better anticipate weather conditions, identify crop diseases using neural networks, provide feedback on machine performance or worker activities, or offer real-time, crowdsourced market data to give tech-savvy farmers a financial advantage, these companies share a fundamental faith in the ability of big data and digital media to "disrupt" farming, and are designed to produce the data-driven "actionable insights" (Schlam 2019) at the core of this new wave in precision agriculture.

Most sensing systems as described in the previous section communicate with integrated, proprietary software platforms, and the business of designing, selling, and maintaining such platforms has increased significantly along with the volumes of data being generated. By the term *platform*, I mean to invoke both its use as a signifier for the "hardware and software framework that supports other programs" in computing (Bogost and Montfort 2007), as well as an apparatus used to curate and shape discourse surrounding digital services and activities, as highlighted and defined by Gillespie (2010). Precision agriculture platforms are designed to operate in any combination of three basic ways. First, as a centralized repository for the agricultural data your farm generates, whether about machine performance, worker activities, or crop behavior, etc. Second, as a processing hub, translating that collected data into human-readable images, quanta, or text. Third, as a management suite for planning and executing farm operations potentially informed by that data.

There are essentially two types of platforms in precision agriculture: systems like Climate Fieldview, Sentera's FieldAgent, or Deere's Operations Center, which are employed in the work of farming itself to run machinery, collect, process, and use data for a variety of ends, for worker or organizational management, telecommunications, or automation, among other purposes. Then there are a class of platforms more akin to Amazon or Facebook, internet-based systems such as Farmobile or Farmer's Business Network that offer a variety of services usually dependent on data generated from other sources, like platforms of the first type. Using Bogost and Montfort's definition, we can generally define precision farming platforms by their distribution across a mix of hardware and software frameworks, usually integrated and inter-operable with one-another. These include a.) computer software suites for laptops and desktop PCs, b.) machine-mounted or handheld units for tractors, combines, and similar farm machinery, which involve combinations of hardware, software, and display/control interfaces for operating sensors, autosteer, and VRT, and c.) software programs/applications on handheld portable computing units, like tablets and smartphones. A more detailed discussion of the discursive and techno-political facets that define agricultural platforms as defined by Gillespie and the gold rush from Silicon Valley and Wall Street for ag data can be found in Chapter 4.

John Deere's "Operations Center" software, a popular, particularly well-developed, and extensive precision agriculture system, exemplifies many of the capabilities and features precision agriculture platforms offer more generally. In Deere's own language, Operations Center is a "centralized online portal that lets you access, view, archive, manage, and share your operation's information" (Deere 2019, 4). This might suggest that Operations Center - like equivalent platforms from other agricultural machinery giants, e.g. Case IH's "Advanced Farming System" or AGCO's "Fuse" - is strictly an internet- or software-based platform of the second type described above, but as Bogost and Montfort make clear, "in many cases, platforms contain other platforms" (2007). A look at Deere's marketing materials, which emphasize that "while other manufacturers bolt-on equipment that may or may not work throughout your production cycle, John Deere develops precision technology specifically for the tractors, combines, sprayers, planters, hay, and tillage products you own…all supported by a single trusted source," confirms that Operations Center, like AFS and Fuse, is the OS-like platform at the heart of the broader Deere precision agriculture "platform" that constitutes the whole of their precision agriculture catalog, connecting and coordinating all of its mechanical, computational, and media elements.

In short, Operations Center and its equivalents consist of bundles of software, hardware, and discursive elements designed for transmitting, processing, and managing farm data through various media organized around a particular way of seeing; in this case a way of seeing farming, farming data, and the objects of farming in terms of systemic digital control embodied in and through that platform. The hardware components include machine-mounted computers, displays, and telecommunications equipment. The software includes the systems for operating that hardware, as well as the operating systems upon which the multiple programs and applications written for PCs and mobile computing devices (smartphones, tablets, etc.) runs. The Operations Center media ecology also includes physical data transfer interfaces, wireless networks, and proprietary telecommunications systems like Deere's cellular and satellite media network JDLink, as well as its cloud-based internet platform, MyJohnDeere.com, which is roughly speaking Deere's equivalent to the Apple Store or an Adobe Creative Cloud account. Those platforms offered by companies akin to AgLeader, Granular, or Climate Corporation that lack the horizontal integration and comprehensiveness a Deere-scale business offers often specialize in higher-quality data analytics or services not offered by Deere's own system, like the seed hybrid variety choice matching or planting prescriptions that seed companies like Pioneer or Monsanto provide. However, given the dominance of the farm machinery business by a handful of major companies, the gatekeeping roles they play (Wolfert 2016), and the reality that a great deal of agronomic data is generated from the "platforms" of tractors and combines, many smaller platforms partner with larger businesses to offer inter-operability between systems.[15] Ultimately, digital platforms like Operations Center play a keystone role in the practical, technical and cultural articulation of 'data-driven' precision agriculture as it exists today.

On the other hand, the past decade has also seen significant growth in the emergence of internet-based startup businesses and industry platforms offering a different model of farm data services than those already described. Usually, these platforms are designed to take existing ag data and leverage it in new ways, often not in direct, primary production roles. The Ag Data

[15] Relatedly, the proliferation of different proprietary data standards has caused significant adoption or useability issues in precision agriculture since its beginning; more on standardization efforts and related farm data issues will be covered in chapter 4.

Coalition, for instance, is a nonprofit group whose stated aim is to facilitate the use of agricultural data by third parties - whether publicly by states or scientists, or privately by agricultural service providers or ag data analysts - by eliminating the technical, economic, and socio-cultural barriers to doing so among farmers (Agricultural Data Coalition 2020). Similarly, there is no shortage of Silicon Valley startup platforms of this class, of which Farmer's Business Network (FBN) has become something of an industry poster child. FBN markets itself as an "independent, unbiased, and objective farmer-driven," "farmer to farmer network" for sharing agricultural data (Farmer's Business Network 2020). FBN is a subscription service where farmers pay to share their precision ag data and related information with the company and one another to create "transparency" about things like agricultural insurance or financing rates, input prices or effectiveness (e.g. what's being charged for X hybrid strain of maize, what did Y variety of insecticide do when you used it), commodities prices, or recent agronomic information about farming conditions (Farmer's Business Network 2020). While I encountered significant skepticism about FBN's motives, value, and efficacy among farmers, researchers and agricultural industrialists during my research, there was also a strong interest, and sense that services and platforms like these will only grow in significance as agricultural data becomes more abundant, and potentially more valuable.

j. Agricultural Data

Which leads us to an important and as-yet unconsidered question: what is agricultural data? What makes data *farm* data, what if anything makes that distinction meaningful, and what effects do definitions of agricultural data have?

Such questions have come to the fore and grown more pressing as “Big Data” in farming has gained a higher profile, as more big data systems are devised for farming that create new opportunities and issues for multiple parties, and as these socio-technical systems exacerbate or accelerate existing problems or innovations. Further, as there is no single agreed upon definition of “agricultural data” in singular currently, questions and confusion concerning its status or uses remain pressing among farmers, the agribusiness industry, and food, technology, and financial institutions invested in American farming. The closest to a universal definition of agricultural data I have encountered is as a catchall term useful for quickly referencing 6 subcategories: agronomic data, land data, farm management data, machine data, weather data, and livestock data. Farmer Business Network’s definition of “ag data” in its privacy policy reflects this: “’Ag Data’ means any agricultural data, as broadly understood in the agricultural industry, including, but not limited to, your agronomic data, application data, climate data, harvest data, invoice data, planting data, land data, machine data, pricing data, weather data, and the type of agricultural products or services you use and purchase from us or other parties” (Farmer’s Business Network 2020). Stakeholders perceive agricultural data as diverse in source and form as the precision agriculture technologies that generate it, leading to difficulties not only in establishing comprehensive definitions, but for creating policies and regulations that meaningfully capture and encapsulate it.

For instance, in 2014, as generation and use of data in agriculture was rapidly expanding (cf. Haire 2014), a group of major private agricultural companies and organizations led by the American Farm Bureau Association (Janzen 2017) assembled to devise and “implement a privately ordered set of norms in the absence of (or to preempt) specific formal regulations governing ag data privacy and security” (Sykuta 2016, 68). This set of principles became the founding “Privacy and Security Principles for Farm Data” for a 501c(3) nonprofit named Ag Data Transparent (ADT) that now formally administers their application and uses, offering evaluations and certification for precision agriculture business’ data “transparency” standards and providing model contracts or agreements such companies can legally and contractually implement in dealings with farmers and other businesses. ADT’s board is composed of individuals from “farmer-led organizations and small, medium, and large ag tech providers,” and is directed by an attorney, Todd Janzen, who is among the most prominent voices shaping legal conversations, licenses, and frameworks for and about agricultural data. Janzen thus influences the direction of agricultural data policy, business, and uses through both his practice and his role as the director of the leading industry voice in matters of agricultural data.

I attended a presentation by Janzen, “Bringing Trust and Transparency to Ag Data Contracts,” in November of 2018 at Purdue University’s Food and Agribusiness Conference that offered an illustrative glimpse at contemporary data discourse among agricultural businesspeople and researchers. Janzen’s presentation was addressed to an audience largely comprised of representatives from across the agricultural and food industries and was designed to help them understand specific problems they will face when crafting contracts and data policies for their technologies or services. This was reflected in Janzen’s definition of ag data from the perspective of agricultural businesses: “ag data means agronomic, land, and weather data generated by ag retailer during any work contracted for farmer.” Explaining further, Janzen referenced and expanded upon the 6-point description of ag data types above, [SLIDE FROM PRESENTATION], making three key claims about agricultural data - “1. data ‘ownership’ is gray, 2. the law does not protect ag data, and, 3. ag data is a hybrid” - that are helpful for moving us closer to understanding what agricultural data is, why agricultural data is difficult to define, and what complexities or problems it raises regarding the establishment of business policies, contracts, clear legal status, and privacy protections.

Janzen's first point is that so-called data ownership in general consists of a "bundle of rights" from a legal standpoint, including the rights to "transfer, consume, exclude, destroy, enjoy, use, possess," etc. Furthermore, data, and particularly farm data, is not equivalent technically or practically: yield, soil, profit, fuel efficiency, precipitation amounts, and milk production data are all "agricultural" data, but are categorically different in source, format, content, and uses. Finally, US law and legal precedent treats data ownership in complex and sometimes counterintuitive ways. Janzen highlighted this by comparing ag data with phonebooks, x-rays, and LinkedIn, where in each case regardless of having a role in creating the data, or it being 'about' you, you nevertheless do not possess ownership rights over that data.

Second, Janzen argued US law does not offer specific protections for agricultural data, due in part to its diverse forms and its specific nature. IP (trademark, patent, and copyright law) and existing consumer protection statues (e.g. those addressing medical, financial, or personally identifiable information) do not apply to agricultural data, and trade secret law, though potentially of limited applicability in some instances, does not suit at data comprehensively. This leaves agricultural data, taken as such, in an undefined position in terms of rights, protections, and privacy concerns.

Finally, and most importantly for our purposes, Janzen proposed that agricultural data is inherently a hybrid type. Consider yield data: a combine equipped with yield monitors and a processing software platform creates that data, but it is of very limited use unless combined with geo-referenced GPS data. Robotic milking machines record what a cow is producing, but it is necessary to tie that machine to a specific cow and farm to make it useful. Accordingly, agricultural data creates and exists in states of legal and ethical uncertainty, prompting industry responses like the ADT standard described above. Yet these definitions and responses raise significant questions and concerns of their own; these will be discussed in greater depth in Chapter 4.

k. Digital Telecommunications

None of that data is of any use, however, if it cannot be quickly and consistently transmitted to computers for processing, which is why most precision agriculture companies rely on media and telecommunications systems at some point in the at data ecosystem. Major precision agriculture corporations like John Deere or AGCO have the resources to provide multiple ways to upload or download data used by, generated on, and stored within equipment-mounted computers – say, harvest data prescriptions or yield results stored on a combine – using USB drives, wireless internet, or even proprietary telecommunications networks like Deere's JD Link digital communications system. Companies like these use the capacities of their comprehensive digital infrastructures as a key marketing point, framing the ease and efficiency of using their platforms to automatically process, manipulate, and represent data as liberatory and empowering. Other precision agriculture businesses or technologies depend upon public or private infrastructure for communications and transmission, and increasingly utilize wireless internet-based distributed server infrastructures conventionally called the "cloud."[16]

[16] E.g.: [Deere's] "Operations Center lets you collect, access, analyze, and share data… on your computer, tablet, or phone... from your office, truck, or even your daughter's volleyball game. One look tells you where all your equipment and people are. You can route the right people to the right place to do the right job, and ensure they have the tools and fuel they need. You can even view your machine's displays remotely. It's like Air Traffic Control for your farm operation … Collecting data on your operation is something you're probably already doing. But that data is of little use to you if it's difficult to access or view. John Deere Operations Center changes all that. It's a centralized online portal that lets you access, view, archive, manage, and share your operation's information … You can see average yield, total yield, average moisture, seeding variety and rates, machine location and more. The

Yet "the cloud" does not cover all land equally, posing a problem for data-intensive, wireless digital media technologies at the core of many precision ag platforms. Due to the rural context within which most conventional agriculture occurs, many farms are located in sparsely populated, widely distributed areas with little to no infrastructural support for robust telecommunications, especially wireless digital media. Government estimates, for instance, show that while in urban areas coverage is around 96%, the countryside has only a 30% coverage rate (Federal Communication Commission 2016). This presents a significant challenge for many contemporary precision agriculture machine technologies and analytics platforms, which tend to focus on capturing, transmitting, and processing large data sets as quickly as possible – the speed with which such data can be accessed and rendered into visual media is a major marketing point for companies like Sentera (Johnson 2018). Similarly, the real-time surveillance of farm conditions offered by distributed sensors like ground spikes are by necessity wireless. Extending their usefulness beyond relatively high-population areas to those where most farming takes place requires spreading the capacity for digital telecommunications over vast territories. However happy John Deere may be to buy as many precision ag startups it needs to offer total vertical integration of farm data technologies within a single proprietary digital ecosystem, it will not finance the construction and maintenance of low-use rural wireless telecommunications infrastructures across millions of increasingly desolate acres in the Plains and Midwest, instead leaving that responsibility to state and federal governments.

Consequently, over the past several years, many of the major stakeholders in precision agriculture have pressured local, state, and federal governments to invest in rural "internetification," an unwieldly name adapted from the title of the 1936 "Rural Electrification

Field Analyzer tool lets you compare these layers side by side. And you can easily share planting, application and yield data with trusted advisors and receive variable rate prescriptions from those advisors" (John Deere 2019).

Act," indicating a mix of efforts to implement different forms of wireless capabilities for rural areas, including remote farms (e.g. Public.Resource.Org 2019). These capabilities include implementing Low-Power Wide-Area Networks, or LPWAN, a technology designed to provide wireless coverage for large geographical areas, at low cost. LPWAN represents an infrastructural keystone for implementing the so-called Internet of Things in a more or less universal way, especially in terms of extending wireless digital telecommunications over large rural areas that traditional broadband companies have eschewed due to the low returns (Mekkia et al. 2019). If in precision agriculture sensors and machines harvest data, and digital media and computers process and render it, wireless telecommunications media represent the connective tissue joining one to the other. Without robust networks that support the interconnectivity of a wide variety of machinery and sensors, the dream of actually implementing an agricultural Internet-of-Things mediating farm operations and environmental phenomena in live or near real-time, would remain hampered by the need to manually transmit data from equipment to computers. In short, the push to implement precision agriculture highlights the reality that it inherently and quintessentially requires a corollary mediation of the countryside, the rural environment writ large, the digitization of the earth - ultimately in the name of surveilling, policing, and governing its phenomena to heretofore unknown scales and degrees, and always has done so.

III. Technologies of the Body

Lastly, we turn to consider what I call technologies of the body, to paraphrase Anne Balsamo's own reinterpretation of Theresa de Lauretis' original expression (Balsamo 1996). These are the digital, mechanical, genetic, and conceptual technologies used specifically to track, order, manage, and control the lives and bodies of plants and non-human animal species in precision farming - a kind of IT-facilitated biopower on the farm.

Many of the technologies outlined above see application in parallel forms in animal agriculture: sensing and monitoring technologies like Radio Frequency Identification (RFID) tags for tracking and inventorying livestock; behavioral and biometric surveillance media like for facial/body recognition or monitoring of biological phenomena like body temperature, stomach contents, or excrement analytics; predictive algorithmic modeling; automated milking machines or feeding systems, and so on. And while genetic technology for selecting, developing, and patenting specific traits in agricultural flora and fauna are often peripheral to machinery-focused definitions or discussions of precision agriculture, the minute engineering of lived environment, biology and behavior in the name of greater control over the properties, productivity, and activities of farmed plants and animals very clearly employ essentially identical logics, discourses, aims, and approaches characteristic of "sub-field" precision technologies like autosteer or VRT.

For example, if we consider plant life, such efforts would include both long-standing achievements in breeding and genetics programs, such as the development of hybrid seed strains in the early 20th century, and more recent uses of epi-and trans-genetic manipulation to isolate and govern specific plant behaviors, among others (Kloppenburg 2004; Pechlaner 2010). Among nonhuman animals, the insinuation of digital and media technologies - including computer-dependent genetic engineering - into the processes of manufacturing, control, slaughter, and management of cows, chickens, and pigs essentially represents the application of "sub field" logics of precision *agriculture* to the individuals, herds, schools and flocks that are the objects of a kind of precision animal *husbandry* known as *precision livestock farming* (PLF).

Accordingly, the following two sections briefly describe (a.) the application of precision agriculture discourse, methods, and technologies to nonhuman animal species known as Precision Livestock Farming, and (b.) the importance of biotechnology, or the use of breeding and genetic engineering of plants and animals to the individual and dividual-scale implementation of precision agriculture.

i. Precision Livestock Farming: precision engineering non-human existence

As for crops and fields, digital and media technologies are now designed and systematically implemented to monitor and control animal bodies and activities at individual and "dividual" scales.[17] These are aimed at offering similar goals as those in precision agriculture: exquisite, encompassing, and continuous control achieved in large part through monitoring systems, computing, and the implementation customized, individualized treatments for each animal as for each plant. The use of precision agriculture philosophies and technologies in animal husbandry is called Precision Livestock Farming, or PLF, and PLF represents the same transition in conventional husbandry precision agriculture names in the cropping realms. That is, PLF describes a program for transforming the object of its attentions, interventions and activities from the scale of populations writ large - undifferentiated masses, the herd or flock - to the individual among the population, increasingly building upon the mass/individual dyad to incorporate newer epistemologies grounded in control and information, from which technologies and methods for achieving dividuated, normalized algorithmic automation have evolved.

[17] "*Dividual*" is a term coined by Gilles Deleuze (1992) to describe the site and form of knowledge and power in the 'society of control,' vs. the 'individual' as the nexus and focus of power of a 'disciplinary' society. Where in the former the individual, defined against the mass and signified by the signature, is a singular and self-contained site of identity, the *dividual* represents instead the individual dissected into component traits, which comprise and are defined through/as "masses, samples, data, markets" divorced from any vital relationship to a self-contained, indivisible unit of identity (Deleuze 1992, 5).

Somewhat unlike commonplace precision agriculture discourse, PLF's debts to "modern control theory" (Wathes et al. 2008, 3) and the tenets of process engineering are more explicit throughout research and industry literature. PLF texts frequently introduce remarkably high levels of theoretical abstraction in their discussions that speak to this genealogical debt. "Animals" - already an immensely abstract categorization - are commonly symbolized even further as components in an idealized system, variables generating "process inputs" to be modeled for a process controller that seeks to achieve a "target value and trajectory for each process output, e.g. a behavioural pattern, growth rate or pollutant emission" (Wathes et al. 2008, 2). Consider the following definitions: PLF is "the management of livestock production using the principles and technology of process engineering" that "treats livestock production as a set of interlinked processes, which act together in a complex network" (Wathes et al. 2008, 2); it is an endeavor to "manage individual animals by continuous [*sic* "every second, 24 h a day, 7 d a week"] real time monitoring of health, welfare, production/reproduction, and environmental impact" (Berckmans 2017).

In short, PLF as a method involves: the objectification of animals as data-generating, dividuated "complex, individually different, time-varying, dynamic" or CITD systems themselves further embedded in larger informatic-mechanical 'control systems,' (Berckmans 2017, 7); a desired outcome that shapes that system's processes of feedback and control; complex mathematical models for processing, prediction and capture of norms and variations towards those ends; continuous real-time mediation and sensing; and "controllers" that materially implement steps to achieve those modeled outcomes through feedback provided by those sensors. Its socio-technical means, considered in greater depth below, consist of a mesh of sensors, computers, algorithms, animals, farmers, workers, and infrastructures that are either wholly constructed (e.g. broiler buildings) or substantially mediated environments (e.g. outdoor pens or grazing pastures) used in service to those ends.

Beyond their shared roots in systems theory, PLF recapitulates all of the key tenets of precision agriculture discourse in the more specific realm of capitalist husbandry: commodification, breeding, slaughter, extraction, marketing, and trade etc. of non-human animals. Global demand for animal products is expected to grow "70% by 2050," necessitating a massive increase in the number of non-human animals being raised for exploitation or butchery (Gerber et al 2013). At the same time, because capitalist development theory requires fewer people work in agriculture over time, the future will likely see significantly fewer farms run by significantly far fewer farmers. Consequently, a future that unfolds along such a trajectory will expect see fewer, in some cases stupendously larger farms - farms of such a scale that some have taken to describing them as "animal cities," containing millions of animals (Opio et al 2013; Macleod et al 2013).

Yet much of the agricultural land already dedicated to animal husbandry is at or near carrying capacity. Moreover, industrial animal agriculture is already responsible for massive shares of the overall agricultural impact on climate, species loss, environmental ruin and ecological decomposition, and such colossal concentrations of single species will further inevitably create new problems in scale and type (Pradhan et al. 2013; 2015). Mirroring precision agriculture discourse on these points, PLF, too, proposes a massive program in the development and implementation of digital, mechanical, and biotechnological innovations to stave off a socio-environmental cataclysm now foretold by the neoliberal eschatology of contemporary techno-scientific global capital. As such, PLF as a system focuses on producing various specific targets and outcomes, namely increasing productive efficiency and intensity. This includes growing animals faster and to greater sizes; increasing the production speed and overall yield of milk, eggs, and other animal products; modeling and controlling animal behavior; predicting, recognizing, and treating endemic and novel diseases; and using the physical environment of livestock buildings to regulate and control production and environmental conditions/pollution in a manner distinctly parallel to precision agriculture's approach to the farm field.

1. Monitoring and Surveillance

The means for achieving constant surveillance in PLF include cameras, microphones, and various sensors placed on or around the animals to be tracked. Cameras, paired with the modeling and algorithmic processors detailed below, can provide not only direct surveillance of a given animal, building, or area, but can be used for real time image analysis of different phenomena or features. These include capturing size or shape features of individual animals, as well as statistics-based analysis of overhead images to determine movement, distribution, or behavior patterns among a group of animals. Such analyses could be used to identify problems with machinery (a broken feeding system, for instance), health (an animal moving less or in unusual ways than is statistically normal for that species), or progress along established "target" parameters. Microphones and other aural technologies can be used independently or in tandem with cameras and sensors in PLF for similar or tandem purposes, i.e. real-time analyses of conditions, such as for comparing near- or real-time sounds from a herd or flock against normal distribution models or identifying specific events of concern or interest.

Sensor technologies in PLF are extremely diverse, both in application and type. Generally, sensors are used on or around the bodies of animals to capture and transmit information about that animal's activities, biometrics, or productivity. There are sensors devised to ID, track, and control animals from the womb to the grave. Such technologies include those for measuring "bio-signals" like body temperature, heart rate, weight, or variously modeled stress signals that can indicate disease, injuries, or other welfare issues [IMAGE OF CALF BEING BORN LEG SENSOR]. There are systems for measuring and monitoring food consumption, internal gastronomic processes, excretion/excreta, and estrus "events" or cycles for breeding or production (collars, swallow-able sensors, 'e pills'). Movement and activity-monitoring sensors constitute another significant group, where GPS position data, accelerometers, RFID tags and pedometers are employed to track, measure, and record activity of various types. Technologies for measuring progress towards production goals include daily or continuous growth or weight monitoring (e.g. for broiler chickens, swine, or cattle destined for slaughter), egg production, and even sensors that measure product qualities like milk conductivity, properties, and yield amounts, just like yield monitors on a combine.

m. Modeling and Control

Algorithmic and machine learning technologies, integral to computational modeling of the large data sets such sensors produce, are the (bio)power generators at the heart of the PLF engineering epistemology. As the previous section highlighted, many sensors in PLF are designed expressly to convey data to algorithms for the purposes of analysis, modeling, and the subsequent implementation of controls. Image data collected from overhead cameras in a chicken broiler house or egg-laying hen's battery cage, for instance, may be compared against existing statistical models of "normal" bodily distributions in a broiler house, or "normal" patterns of movement within battery cages to assure productivity goals in chicken rearing. Algorithmically-achieved facial or bodily recognition and other biometrics are of increasing importance in PLF, which are useful for not only enhancing, augmenting, or replacing existing identification management systems, like collar, tag-based, and even subcutaneously implanted RFID technology, but for moving into new areas of research and analysis altogether. There are, for example, significant efforts underway to use digital surveillance for data to establish behavioral and personality profiles and typologies for different species, towards the end of greater prediction and control of the production process (field notes on presentations, cite their publications).

Modeling of normal behaviors is in fact an essential application of big data and algorithmic processing in PLF, and serves as a foundation for not only the kinds of baseline-comparisons already mentioned, but for predictive modeling and pattern recognition intended to avoid problems before they arise, or to create conditions amenable to the implementation of automated ‘process control technologies.’ It is increasingly common to see digital surveillance and algorithmic processing used for biometric trait assessment and behavior analytics, or for determining things like feed amounts or medication regimes for livestock, with the goal of more intricately controlling and optimizing things like milk productivity (Doreá et al. 2018). For instance, if the “behavioral repertoire” of a pig or turkey is mapped to a degree of statistical comprehensiveness, i.e. establishing the likelihood that a species of animal would react in a certain way in a given situation, that pattern can be integrated into robotic feeding, watering, or harvesting technologies, which can in turn have entire infrastructures designed around their implementation. Robotic dairy milking machines, for example, require not only significant research into what cows “like” and “dislike,” they need specific architectures to house and operate them effectively. Once built, such facilities can iterate further automated systems into the automated milking process: feeding, digestion analysis, weighing, temperature checks, stress or progress indicators, etc.

Given the above, we can conclude that precision livestock farming's methods and aims largely mirror those in crop precision agriculture. They share conceptual and rhetorical genealogies rooted in cybernetics and systems theory (among others - a lineage explored in the following chapter), a focus on opening up new individual and dividual scales of intervention and management, and methods, technologies, and goals aimed at producing greater command, control, communications, and information, to name only a few. As the final brief section that follows attests, both PA and PLF also extend and intensify an existing history of breeding, eugenics, and selection organized around productivity and capitalist rationalization imperatives, the final piece in the overall suite of precision agriculture control systems.

ii. Biotechnology: precision engineering non-human life

A corollary of the statistical behavioral and biometric modeling described immediately above - which takes whatever species as a kind of informatic set, a "given," reducible to a series of normally distributed body sizes, capacities, traits behaviors, tendencies, diseases, productive abilities, etc. - is to question to what degree one needs to take that basic set of information *as* given. If one can not only mold technologies around the shape of a life or a body, but can shape that body and life to better suit the limits and specificities of your technology, why would one stop there? This is precisely the dream of contemporary agricultural biotechnology, where genetic engineering techniques open up the ability to "manage livestock in such a way that the animal's productivity is closer to animal's genetic potential; less use of feeder, less manure, and higher productivity" (Berckmans 2017, 6). If genomic mapping and gene prediction have revealed that a given species falls far short of reaching its full "genetic potential," new "precision" genetic engineering technologies like CRISPR and the gene drive offer the means for targeting and retooling the operating system, so to speak, of your cattle. These then are the second group of technologies of the body, those biotechnologies designed not to control the way a life is lived, but the body and life itself.

Biological engineering ("bioengineering") as a contemporary technology is a profoundly computational, informatic system. It depends upon computers for research, modeling, production, and implementation, and more critically, it rests upon on a reductionist epistemology that renders a living thing *in toto* in terms of a kind of pure informatic chattel, a body of raw data, information-qua-commodity drawn from a life-qua-commodity, just waiting for better, smarter, more precise programming than ungainly and slow sexual breeding techniques to help it fulfill its (eu)genetic destiny. What had to happen to be able to view any given "living organism" as a Complex, Individually Different, Time-Varying, and Dynamic System? We will briefly review that mid-20th century history of biology's reorganization on information-based epistemological foundations in the following chapter. For now, it is enough to observe that the legal conditions for bioinformatic engineering and commodification of flora, fauna, and fungi - of lives and living things *as such* - were progressively established and expanded by a series of Congressional acts and Supreme Court decisions over the 20th century. The first step was taken with the passage of 1930's Townsend-Purnell Plant Patent Act (more on this below)[18] which established a new legal category for patenting asexually reproduced and non-tuber plants. This law was the result of 30 previous years of research and lobbying inspired by the resurrection of Mendel's genetic work, which ultimately saw widespread success in efforts to privatize and

[18] Act (Townsend-Purnell Plant Patent Act, ch. 312, § 1, 46 Stat. 376 [1930] [codified as amended at 35 U.S.C. § 161])

commercialize certain types of agricultural science - particularly those related to hybridized seed stock for row crops, especially maize.

n. Hybrids and Intellectual Property

In the 19th century, Darwin-inspired biologists seeking to understand the mechanisms of heredity discovered what is now called the principle of *heterosis* - that individuals born of parents from different genetic lineages are dependably more "vigorous" than those that come from the same strain (Kloppenburg 2004). Hybrid seeds, however, while more robust and predictable than their parent stock, do not themselves beget healthy or productive offspring. Contrary to the basic evolutionary trajectory of most forms of life, hybrid plant varieties thus tend to create their own scarcity. If typical seeds are like factories that produce more factories, hybrid seeds are like traditional factories producing single-use perishable consumer goods. This accident of nature was critical to the commercialization of crop agriculture, because a product that makes more of itself is not effective at creating repeat customers; "self-destructing" wonder seeds, however, mean a farmer will likely be coming back for more. Thus, if farming was to be more fully integrated into the order of capitalist liberalism - the rationalized industrialization of production and social relations - that had transformed so many *other* dimensions of life over the previous centuries, a profitable, private seed industry based on the newly perfected hybrid seed needed to achieve three things. It had to reduce or eliminate competition from "(1) farmers (who may save their own seed for planting the next cropping season), (2) the public research system (which has historically developed new, improved crop varieties), and (3) other seed companies" (Buttel and Belskey 1987). The very infertility of hybrid offspring provided the limited, profitable, and controlled market for something that previously simply grew itself. Not only did hybrid seeds offer artificial control and limitation of seed supplies, the fact that they required large investments in research and very specific conditions of production laid the groundwork for further commercial controls in the form of intellectual property restrictions.

Private agribusiness interests began organized lobbying to privatize these commercially important forms of biological research beginning around the turn of the century (Stansfield 2006). The emerging seed industry successfully ended public seed distribution programs in 1926, and secured landmark patent protections for asexually-reproduced (namely, hybrids) and non-tuber propagated plants with the aforementioned 1930 Townsend-Purnell Plant Patent Act. The Townsend-Purnell Act was a milestone in the privatization of agriculture, establishing the legal foundations for future extensions of patent protections, and, ultimately, the groundwork for redefining living things as a form of not just chattel, but privately held intellectual property. It also created one of the essential conditions for new and intensified forms of mechanization and chemical inputs in agriculture now called conventional or factory farming.

This condition was the knowledge, and ability, to "manipulate plant architecture" (Kloppenburg 2004, 36). Lack of specific, actionable knowledge of plant biology prior to Mendel had hindered or prevented the industrialization of most facets of farming, because "the development of pesticides and herbicides had to await the elucidation of hormonal processes and other pathways of biological action in insects and weeds" (Kloppenburg 2004, 36). Appropriation of the elements of farming, its mechanization and industrialization, was made possible both through that biological understanding, and the legal restrictions that made commercializing that understanding profitable. Between the 1920 and 1950 most of the key elements in conventional/factory farming were established or expanded to dominance: the expanded and centralized roles of the financial industry and commodities markets, which encouraged monocropping and am emphasis on yields over diversity and self-sufficiency; the substitution of machines for manual or animal labor; the widespread introduction of artificial agrochemicals (fertilizers, pesticides, antibiotics/hormones), etc. (Fitzgerald 2003). Almost all of these developments depended to some degree on the increased ability to make living things amenable to mechanization and industrialization, and for the products of those efforts to exploit a path to profitability via patent protections (Buttel et al 1987; Perkins 1997). These restrictions - and the commercial opportunities they entailed - were further expanded in 1970 via with the Plant Variety Protection Act, which created patent-like protections and exceptions for the tubers and sexually reproduced plants excluded by the original 1930 Act. The most significant and influential ruling arrived a decade later with the 1980 supreme court decision in *Diamond v. Chakrabarty* 447 U.S. 303 (1980), which granted historically unprecedented legal rights, permissions, and conditions for patentability of living things and life processes, creating the foundations for modern biotechnology and genetic engineering in agriculture.

o. Genetically & Transgenically Modified Organisms

The Supreme Court's decision in the *Chakrabarty* case granted that nonhuman animals - and their biological processes - are legal property that meet the conditions for patentability as a "manufacture" or "composition of matter" under Title 35, Section 101 of the US Code, which defines and describes patents and patent requirements in US law (Title 35 – find citation style). In effect, *Chakrabarty* reclassified the legal standing of living things in such a way as to essentially guarantee further patent restrictions would be applied to life and life processes in the years to follow. The case was brought over whether the right to patent a bacterium - in and of itself - existed. The decision in favor of Chakrabarty, the defendant and genetic engineer, was based on an extremely broad and selective interpretation of §101 which concluded that "anything under the sun that is made by man" qualifies as patentable, and that modifying a bacterium to do something it had not previously qualifies as "making" "by" "man" (Goldhamer 2014). The Court used this interpretation to rule that a GMO bacterium he had modified in a company lab to metabolize a substance it otherwise did not constituted, in and of itself, a kind of "manufacture" or a "composition of matter" (the Court never clarified which), and thus met the requirements of §101. This decision created the legal grounds for classifying essentially any non-human living thing or biological process "under the sun," modified by human beings in any legally legible way, as a patentable "manufacture" or "composition of matter." Consequently, beginning in the years immediately following the *Chakrabarty* decision private biotechnology firms have invested millions of dollars in research and development of genetically modified non-human plants, animals, bacteria, and other forms of life or life-processes that hold commercial promise (e.g. Hammer et al. 1985). This has been particularly true among agriculturally important plant and animal species, given the multiple potential for profitability they offer.

Presently, plant and animal species are biologically and genetically modified in a wide and growing number of ways, and for a myriad of human-centered purposes. Most of this modification remains in the research stage, or awaiting government approval for sale, however; GMO livestock, unlike GMO plants, have only jus

t begun to receive permission for sale in the United States, and so far only in very limited cases (Briscoe 2019). Generally, the goals of this engineering can be sorted into three basic categories, any one or combination of which can motivate that engineering. These goals are 1. to create or intensify selected economically beneficial traits in a species, 2. to increase efficiencies in the production process, including reducing waste and/or contributions to pollution and environmental destruction, and 3. producing raw materials using other species as living manufactories or research mediums, and/or contributing to human health through use as a medium in scientific research, testing, or production, practices known as "pharming" (Forbasco et al. 2013).

Engineering beneficial traits in plants and animals involves myriad efforts to exploit, increase, or control different qualities that increase the economic value or utility of a creature. Increasing the growth rates or overall possible sizes of agriculturally significant species is one such goal; livestock, in particular, have been the subject of significant research into transgentics towards this end. Human growth hormone and chicken proteins, for instance, have been inserted into pigs to increase their rate of growth, muscle volume, and size of economically important body parts, while reducing the amount of feed necessary to achieve those results (Forbasco et al. 2013). "Double-muscling," the creation of two muscle layers instead of one in order to increase the available meat for harvest, has been achieved in both cows and trout (McPherron et al. 1997; Medeiros et al. 2009). Similarly aimed experiments have been performed on sheep and fish in particular; among the first patented transgenic animals, the AquAdvantage salmon, was engineered in 1989 to resist its seasonally-attuned growth pattens in order to reach full size in 16 months instead of three years - it was approved for sale in US markets in 2015 (Pollack 2015). Mouse and cow genes have been microinjected to increase the amount of milk produced in sows, and to increase its bacterial resistance (Lo et al. 1991; Wheeler et al. 2001). Both pigs and cows have been modified with human lysozyme to that latter end; for mammals and birds forced to live in enormous, crowded, and confined industrial conditions, devising new and more powerful ways to combat bacterial and viral infection is viewed as critical to the future of animal agriculture, as noted previously (Forbasco et al. 2013). Infection and sickness are extremely pressing economic problems in animal husbandry, as they significantly and constantly threaten the profitability and overall efficiency of a livestock operation. Consequently, most major forms of livestock have seen some modification experimentation towards this end. Goats, sheep, and chickens have all been genetically experimented on for disease prevention using bacterial, virus, and cow genetics (Forbasco et al. 2013; Long 2014). Other efforts have focused on transforming the compositional 'healthiness' of meat, milk, and other animal products relative to humans, including lowering the fat content of milk, producing leaner meat in pigs, and inducing faster wool growth in sheep (Rogers 1990; Reh et al. 2004; Saeki et al. 2004).

Engineering for productive efficiency and reducing environmental effects involves crafting mental or biological activities to better suit industrial conditions, and/or consumer desires. Increasing the effective biological use or "conversion" of inputs like feed or pharmaceutical treatments is one such goal. More efficient use of inputs should theoretically reduce both the amount required to do the same job, as well as ideally limiting the "output" of excess or incompletely metabolized inputs in urine, manure, and field runoff, which are a primary cause of environmentally ruinous phosphorous and nitrogen-induced algal blooms and dead zones in major waterways. Chickens have been modified to metabolize lactose, which they otherwise do not - the idea being that cheap or excess lactose-containing "energy sources" that would otherwise be discarded could instead be used as feed (Mozdziak 2003). The "Enviropig," another patented and (conceptually) branded animal like the AquAdvantage salmon, is a pig engineered to metabolize phosphorous it otherwise wouldn't (Forsberg et al. 2003). While this transformation offers no direct benefit to consumption - it would not make their flesh taste any different - it does afford marketing opportunities for producers, possible mitigation of negative press surrounding the environmental impacts of factory farming, and potential cost savings on inputs or environmental mitigation efforts. Related environmentally-oriented genetic engineering efforts are engaged in attempts to reduce endemic and virulent diseases encouraged and maintained by the high-intensity, high-concentration conditions of industrialized animal agriculture. This is not only in order to reduce economic "losses" in the form of sick, under-productive, or dead animals and plants, but to protect against any animal-borne pathogens that may threaten human well-being (Kues and Heiner 2004). Efforts are also underway to combat the serious economic threats that "invasive" species at every taxonomic scale present to agricultural industries, including the development of gene drive technologies for transforming or even eliminating entire species within several generations by inserting what amount to suicide genes (e.g. Thresher 2008).

Physically designing and shaping nonhuman animals to better suit factory-style production conditions in CAFOS is another critical area of research in this field. For example: female chickens destined for egg laying normally have their beak tips burned off as chicks for the same reason (most male chicks are not subject to this practice, because they are instead thrown into large grinders due to their low economic value), and dairy cows have their tails docked or severed completely to avoid the increased chances of trampling and infection confined factory conditions produce. Practices like these are potentially rendered moot, however, if these modifications for the factory environment can be made genetically, before a creature is ever born. Bovine breeds with normally large horns, for instance, have been engineered with smaller or no horns by inserting the genes of hornless breeds, which from the perspective of farmers suits bulls to confined, cramped quarters better, mostly by prevent gouging and other economically harmful injuries (e.g. Regalado 2014). While many such efforts are focused on making animal bodies suit the ontology of the factory, and thus more factory-like, others are intent on making the ontology of the factory more portable, or less constrained to specific sites or habitats, using animal bodies as media. Transgentic insertion of arctic fish "antifreeze" genes into salmon, for instance, is aimed at opening up entirely new areas of the Arctic to industrial fish farming that would be otherwise limited by the bodily realities and capacities of natural salmon (Hew et al. 1999).

It is increasingly common to see digital surveillance and algorithmic processing used for biometric trait assessment and behavior analytics in plantlife as well as among nonhuman animals. At an NSF conference on machine learning in agriculture I attended in 2017, Prof. Dan Schnable of Iowa State University described how precision technologies of the biological type build upon efforts to engineer certain crops to "tolerate crowding better," research underway since the 1930s. Using overhead time-lapse photography, researchers have observed the leaf rotations of specific hybrid lineages over the course of a day. Linked in tandem to their genetic profiles, this research is designed to identify and map "the genetic determinants that allow plants to rotate, or not to rotate" (Schnable 2017). The goal is to engineer a new stratum of discipline into the already countless "rows upon militant rows of corn" (Gaalaas-Mullaney 2015), policing the bodies of maize down to their very comportment such that they disobey their most ancient and natural yearning – to greet and follow the sun – to instead stand stock still in total uniformity, like soldiers in perfect lock-step.

Finally, "pharming" is an extremely interesting practice; some examples include the engineering of livestock to produce pharmaceuticals or even raw manufacturing materials in their milk or flesh, or using livestock as media to grow human organs for so-called "xenotransplantation." Pharming, though intimately related to the thesis of this project in both its epistemology and methods, is only peripherally relevant to the more central concerns regarding precision agriculture at hand, and thus will not be considered further.

To summarize this brief look at the engineering of plant and animal environments, and how exactly they relate to precision agriculture, I will turn again to Schnable and his comments at the NSF meeting. During his presentation, he emphasized that “the corn of today is not the corn of the 1930s, so the improved practices we use now would not apply to those strains; they’re very much two parts of a system” (Schnable 2017). That precision agriculture is a fundamentally *interdisciplinary* field was stressed repeatedly over the course of the weekend; it “combines biology with engineering” as plant scientist Anja Getimann expressed during that same meeting. Even this brief outline of technologies of the body in precision agriculture, and the handful of examples shared here demonstrate that not only are PLF and biotechnology explicitly complementary in their aims and often means - engineering animal lives and bodies to better suit the industrial process - both are in turn similarly congruent with the aims and methods of precision agriculture writ large. That is, both crop and animal agriculture, as *precision* agriculture, share a basic and essential conceptual, technological, and discursive genealogy that produces strong similarities across both the many different varieties of farming, and the many different scales of intervention and development within those varieties - the processes and operations that constitute the overall apparatus of conventional farming. That genealogy is the focus of the following chapter.

IV. Conclusion

This chapter’s purposes have been threefold. First and foremost, it was intended to familiarize unfamiliar readers with precision agriculture as a system. Second, it was meant to illustrate what proponents and boosters of the precision agriculture "revolution" mean when they invoke that phrase, to show what this discourse is based on and what it signifies. In other words, this chapter was meant to illustrate the details of the revolution such proponents and commentators see. By exploring and outlining these systems, tools, and methods, this chapter was also intended highlighted a series of technological, epistemological, practical, and material commonalities circulating across the formation called *precision agriculture.* Describing the sources and effects of these commonalities is the task at the heart of the following chapter, including themes or concerns that, whether tacitly or implicitly, were repeatedly emerged in the course of this one: things like the various forms of legibility demanded of agriculturally significant phenomena by both state and capital, the rationalization of land, methods, bodies, settler-colonialism and imperial states, even the notion of information serving as a kind of connective ontology as much as a kind of simple technology. The backgrounds and common histories connecting these concerns, issues, and phenomena are the focus of chapter 3.

Chapter 3 illustrates and builds upon a central claim of this dissertation: that precision agriculture is not revolutionary, but to the contrary represents the evolution and intensification of longstanding historical realities visible and manifest in those very connections. These realities include not only the existing 20th century processes of mechanization, mediation, and informaticization, but the importance of the historical development of capitalism, liberalism, centralized states, and the sciences of "police and good order" that were at the heart of the rationalization and industrialization of agriculture that created and *define* "conventional" agriculture - and its precision articulation - as such.

CHAPTER 3: THE INFORMATIC IDEAL

I. Introduction

This and the following chapter critique the dominant narrative of precision agriculture as a disruptive, revolutionary force by considering two core and inter-related critical elements of precision agriculture as an apparatus. On one hand, the ways in which discourses of revolution & techno-saviorism that conventionally accompany digitization or "smartification" (Halpern et al. 2017) initiatives are better understood as an intensification and evolution of conventional, capitalist agriculture. And on the other, by extension, the character of environmental mediation of the type represented by precision agriculture as a form of what I will describe in the following chapter as the "government of nature," aimed above all at maintaining and expanding the power relations that enact and characterize contemporary, conventional agricultural and food systems.

This chapter critiques the rhetorical and epistemological foundations of the claim that precision agriculture is a disruptive, revolutionary force. This claim portrays precision agriculture as a phenomenon that will save the environment while feeding the world, all while creating new economic opportunities and propelling the world forward into the dawn of a new informatic age, radically, even ontologically different in character from our inefficient present. It grounds these assertions in the historical, socio-cultural, and political contexts overwhelmingly absent from contemporary precision agriculture discourse and design practices. It explores how, like the "Green Revolution" before it, precision agriculture's dominant rhetorical framework is drawn from a deeply insinuated mangle of normative assumptions – hegemonic and presumed truths that are left largely unquestioned and intact across the scientific, industrial, and political milieus of precision agriculture discourse. These assumptions both inform and are co-produced by the algorithmic and data-centered technologies at the core of precision agriculture practices.

In contrast to its popular representation as a disruptive technological savior and radial break with the past, I argue that the current development and deployment of precision farming represents above all a digitally-augmented effort to shore up and maintain the existing socio-political, cultural, and economic order of capitalist agriculture: the monocultural production of input-intensive commodities organized and propelled by the need to compete in markets and constantly increase productive output. Contrary to the often determinist, weakly historical lenses through which it is regularly and publicly projected, precision agriculture is better understood as a material and conceptual expression of deeper and more diffuse historical lineages: namely, the political-ontological webs uniting capitalism, government, and technologies of quantification and information management as machines of surveillance, command, and order. In short, precision agriculture is a technoscientific assemblage of control in the Deleuzean sense *par excellence* (Deleuze 1992).

Like countless other fields, presenting digitization in farming as disruptively progressive, beneficial, and indeed necessary is a central rhetorical facet of precision agriculture. Connecting this to an epistemological, even ontological "revolution" is a part of what I call the "informatic ideal," which I argue is augmenting, modifying, and at points supplanting the extant rationalist "industrial ideal" described by Deborah Fitzgerald (2003). The discourse of the industrial ideal is rooted in and expresses the overwhelmingly technologically determinist character of Silicon Valley, where in agriculture it is reproducing its well-documented harms in new ways; harms all the more egregious given the social and environmental reach of agriculture. This chapter will briefly introduce this concept/argument as a means for understanding the specific cast of digital revolution/disruption rhetoric and its emerging discursive power within US agriculture, laying foundations for further development of this concept and argument in future work.

Activists, politicians, critical scholars of technology and media among many others have worked hard for decades to highlight the history and combat the harms of digital technology as a socio-technical system and techno-political force, whether in terms of the decay of privacy and omnipresent surveillance, the increased imbalance of corporate and state power, the un-democratic, misogynist, racist, ableist realities embedded in many complex technical systems, or any other number of issues in a long and fast-expanding list. In other words, there are significant and expanding movements to ensure equitable, democratic design and uses of digital technology in terms of their harms for humans, in many forms at many scales. But the techno-politics of digital agriculture not only present precisely the same issues for humans within the farming industry, they open up and extend such concerns exponentially in consequence beyond the figure of the individual, rights-bearing person. Whole environments, ecological families, cascades of different species and beings are directly and multiply harmed, let alone affected by the maintenance and intensification of conventional agriculture through digital means in countless ways, from destruction of not only life itself but ways of life, of untold cultures, of the very conditions of possibility for vitality writ large. As this chapter will argue, it is therefore essential to critique and combat the dominant discourses and imaginaries urging for and shaping this precision "revolution," because agriculture writ large is a truly planetary force, with outsized environmental and political consequences ranging from the global to the infinitesimal for humans and non-humans alike.

To do so, this chapter will 1. present the core discursive properties, rationale, and a brief genealogy of the digital revolution imaginary – the informatic ideal – as adopted by advocates of precision agriculture, 2. provide a critique of this discursive ideal, historicizing and situating it socio-politically in the history of rationalization, quantification, and control via information technology as propelled by the development of capitalism and the contemporary state-form, and 3. briefly present an alternative theoretical lens for understanding and characterizing the informatic ideal as embodied *qua* precision agriculture, understood as a social, political, economic, and environmental force: namely, as an anti-democratic dream of "code as law as police *de grain*." This discussion will set the stage for the discussion of the dream of the "government of nature" to follow in the next chapter.

II. Revolution, Disruption, & the Informatic Ideal

i. Revolution

I am sitting in the cavernous *Salle de Bal* of Montréal, Québec's Centre Sheraton. It is 8am on a Monday, June 24th, the summer of 2018. Alain Houde, a representative of Canada's equivalent to the USDA – the Department of Agriculture and Agri-Food – welcomes the audience gathered there for the 14th annual International Conference on Precision Agriculture (ICPA), held by what is arguably the most prominent major organization in precision or digital agriculture, the International Society of Precision Agriculture (ISPA). Addressing a crowd of government officials, industry reps, academic researchers, businesspeople, and a handful of farmers, Houde opens his introduction with a declaration: "Precision agriculture is the wave of the future, and you are the forefront of that wave."

From that point to the close of the conference, techno-futurist farm rhetoric was the water I swam in. At every panel, in every address, on every pamphlet, a specific invocation could be found, a grace-like prayer invoked before seemingly every discussion of agriculture's digitization. The discursive architecture of this futurist chant is specific. It takes a particular and consistent shape, marked by three features: a characterization, two threats, and two promises.

The threats go like this: by 2050, the world population of human beings will rise to 9-10 billion;' and, consequently, '"we" must increase food production by [X = a number varying from 50-100%] by that time in order to prevent a global famine. The promises follow: information will deliver us. Precision agriculture will not only produce transformative economic efficiencies, rescuing hard-pressed farmers from financial ruin, such efficiencies and powerful controls will help stave off the catastrophes of climate change, global warming, and ecological decay (unspoken is the spectre of social and political unrest haunting each of these). Precision agriculture, in other words, is efficient, environmental, and necessary. Taken together, the above is offered in every preamble as evidence of precision agriculture's character: it is nothing if not *revolutionary*. Wherever precision agriculture is entreated by that or any other name, it is likelier than not one will find the terms "revolution" or "disruption" hard by; precision agriculture is presented as both embodiment of and precipitate for the "4th Industrial" and "3rd Green" revolutions, a "wave" of disruptive innovations that will transform the world.

Houde for instance quickly developed his claim along these lines, asserting that precision agriculture offers "increase profit with reduced inputs," "increases farm income while protecting our environment," and is the answer to the question of "how to feed the world sustainably; over the next 30 years, farmers will have to produce 60% more food, and they will have to achieve it while reducing their carbon footprint." In the keynote speech that followed, Chris Paterson, a project leader in Bayer's Digital Agriculture research division, drew on the same devices to illustrate why farming is "more [complex] than rocket science," and is only growing more so (2018). Paterson reproduced the rhetorics of population growth and land/environmental constraints, and spent some time outlining what he presented as the solution: the explicitly disruptive nature of precision agriculture, linking it to developments in "artificial intelligence" and quantum computing that promise machines that "compute at the same rate as a human brain."

In these and an immense array of related spoken and print accounts, precision agriculture is repeatedly portrayed as a confluence of cutting-edge digital technology with the promise of profound savings in labor, inputs, and pollution, combined with a vision of greater control in an undeniably difficult and unpredictable profession. It, therefore, offers a look into an illuminated future against which Houde, Paterson, and countless others tend to frame our comparatively benighted present. The most prominent claims for precision agriculture's revolutionary, progressive, environmentalist character rest on this argument – that digital technology allows farmers to abandon an older, more geometric, more totalitarian form of conventional farming in favor of a targeted, enlightened, controlled future. Any farmer who possess the precision technologies and digital techniques outlined in the previous chapter, this discourse holds, should be able to make truly informed management decisions about what crops to plant where, in what amounts, and with what treatments; a special boon for those farming poor soil or on difficult terrain. Combining these disparate elements into a single, quantified picture builds a faith among some farmers in these aggregated, algorithmically regulated pictures as more correct, more accurate, and more precise. As one Indiana farmer explained, this data-driven rigor is a big part of the appeal of PA technology: unlike subjective, fallible human observations, "the combine will tell the truth; when you go through your machine, you know it's right."

The allure of this glittering algorithmic promise – to grow more with less, while mitigating the negative environmental effects of conventional farming and helping guarantee food security for a rapidly growing world population – has led a growing number of farmers to invest in harvesting data along with their soybeans (Schimmelpfennig 2016; Wolfert et al. 2017).

It has also led to some striking claims about "digital disruption on the farm," (Ryder 2014) and of precision agriculture as a revolutionary agent of "technological alchemy" (Brummel 2014).

In truth, as noted in the introduction, proponents of precision agriculture rarely miss a chance to call it a revolution – sometimes even more than one. Examples of disruption and/or revolutionary ideation are exceedingly common in precision agriculture discourse; for the sake of further examples of both in research literature see Santhosh et al. 2003; Grose 2015; Debats et al. 2016. This usage is equally *de rigeur* in reporting and media texts. Even the relatively limited body of existing critical scholarship on precision agriculture tends to frame it this way: among the earliest of the recent wave of critical attention to PA, Bronson and Knezevic (2016) open their commentary on "Big data in food and agriculture" with the declaration that "farming is undergoing a digital revolution." Similarly, sociologist Michael Carolan, who has staked out a significant claim on the critical study of precision agriculture with barrage of recent publications, describes the datafication of farm operations in a similar idiom: "it is a bit of a surprise that social scientists are only beginning to critically analyse and understand what the big data and precision revolutions mean for farmers and food futures more generally" (Carolan 2018, 749).

While these and a handful of other scholars (Carbonell 2016; Schiller and Yeo 2016; Murray, 2018) have articulated much about the datafication of farming, little attention has been paid to the cultural and discursive constitution of the system known as precision agriculture.[19] This chapter seeks to address that gap with a critique of the glittering imaginary of algorithmic disruption and digital revolution in US agriculture. "Precision farming" is shorthand for efforts to reorganize conventional farming's epistemological and professional foundations around informatic, algorithmic principles. Drawing on culturally and rhetorically-focused scholarship in

[19] One exception is Nick Murray's outstanding article in Viewpoint Magazine on the relationship between country music, farmer identity, corporate control of agriculture, and the rise of precision farming (Murray 2018).

Media Studies and STS, this chapter builds upon the argument Wolf and Buttel (1996) advanced over 20 years ago: that far from revolutionary, precision agriculture is better understood as a normative force—cutting-edge means for overcoming issues endemic to the industrial production of agricultural commodities and preserving capitalist modes of production. Like the "Green Revolution" before it, precision agriculture as it exists serves more to stave off a genuinely political "Red" revolution of redistribution and extension of democracy than precipitate meaningful change, in effect offering technological solutions to social, political, and environmental problems. Such solutions appear designed to leave the conventional, market-oriented farming system responsible for many of these problems intact. In short, contrary to its dominant expression, I argue that precision agriculture *is* conventional agriculture.

Major agricultural companies like John Deere, AGCO, Monsanto, Bayer, Syngenta, Du Pont, and Cargill have all invested heavily in PA technologies, serving as key drivers of its development and adoption over the past several decades. These industry giants have been joined by multitudes of Silicon Valley startups, drone manufacturers and other adjacent industries, and increasingly finance and Wall Street, each seeking to exploit emerging niches in this rapidly digitizing field. Often these companies operate from the very offices disrupted into existence atop the nation's highest concentration of superfund sites in San Jose, a legacy of the material costs incurred in actually manufacturing the foundations of aethereal cyberspace, all sitting within a once famously fertile agricultural valley.

Yet whenever I encounter this incessant refrain – more food, less harm, and greater savings for farmers thanks to big data and fast computers – I am reminded of something a Cornell agricultural scientist working on drone-mounted crop recognition sensors said to me in 2017: "I feel like I'm training my replacement." A closer, more thorough look at the complicated mix of forces driving precision agriculture reveals that its benefits are far more ambiguous, and much less evenly distributed, than current accounts claim. What has changed since Wolf and Buttel wrote is the emergence of a language of algorithms and data-driven insights lending new persuasive epistemological force to PA. Any contemporary critical analysis of precision agriculture that does not depart from *a priori* technologically determinist grounds quickly suggests that digital farming's emergence presents serious and *negative* implications for social equality and every environment it touches, including worker surveillance and oppression, accelerated agricultural consolidation, ethically catastrophic treatment of nonhuman beings, a flood of financialization in farming, and the overall support for the persistence of a ruinous agricultural system. Whether called smart, digital, or precision agriculture, farming of this kind, characterized in this way, is emblematic of a wider cultural and economic trend to seek solutions to food issues in digital technology (Cf. Miles and Smith 2015), with food production in general seen as a "challenge to be addressed using information technology" (Simelli and Tsagaris 2015).

While usually presented as a break with the past, the high-tech algorithmic patina of precision agriculture obscures the reality of its historical continuity and *evolutionary* character, an intensification of well-established features of conventional farming. This is not to suggest that the datafication of farming is without its own specific consequences—that digitization of farm operations does not represent any change whatsoever. The shift from a kind of disciplinary, whole-field management style towards an individualizing, even dividuating informatic system of sub-field control has already raised new issues in conventional farming, from concerns about automation, to rights over data, to consolidation and the acceleration of urbanization. But, as I will argue, these issues stem from the deeper grammar of capitalist organization of production and fundamental liberal capitalist tenets of individuality, social order via efficient free markets, and a faith in rationality, rather than the technologically determinist image of data-driven "revolution."

ii. Disruption

There is more to the rhetoric of revolution than, for instance, the everyday marketing hyperbole of the past several decades which uses "revolution" as a constant refrain finally percolating into the further reaches of rural America. Its contemporary usage owes much to the introduction and adoption of two 20th century economic concepts: "creative destruction" in 1942, and "disruptive innovation" in 1997, and reflects this genealogy in its uses and discursive effects. Today, the use of *disruption* almost inevitably follows any commercial development of a digital technology (particularly when a formerly non-computerized activity or thing is subjected to digitization), owing to its etymological and cultural development propelled by the staggered influence of these two concepts.

The notion of "creative destruction" was first developed in its modern and most influential sense by Austrian economist Joseph Schumpeter in his 1942 book *Capitalism, Socialism and Democracy.* Schumpeter famously drew on Marx's observation that capitalism, and the market-based social order that characterizes and reproduces it, creates powerful imperatives that drive a race among the owners of the means of production to constantly increase efficiencies, productivity, profits, accumulation. This, Marx and Engels observed, means that "all that is solid melts into air" as permanent change and turmoil are the quintessence of everyday life under capitalism (Marx and Engels 1988, 58). In their words, "constant revolutionising of production, uninterrupted disturbance of all social conditions, everlasting uncertainty and agitation distinguish the bourgeois epoch from all earlier ones" (1988, 58).

Schumpeter described this central feature of capitalism as “creative destruction” in his 1942 work, ultimately affirming Marx and Engels’ analysis that capitalism would ultimately undo itself and eventually give way to any number of “socialist” social forms in its wake. By no means a Marxist himself, Schumpeter’s key move here was a recharacterization of this account of capitalist turmoil. Classical Marxist arguments suggested that the market forces that compelled greater productivities and efficiencies inevitably led to falling profits and “immiseration,” as this process would inherently compel capitalists to exploit their workers with increasing brutality in order to continue extracting adequate surplus value for reinvestment and profit. In their account, this situation would only persist and increase, immiseration intensifying worldwide until it produced an inexorable violent reaction by an increasingly organized working class – a political revolution, in which the “expropriators [would be] expropriated” (Marx 1976, 929). Schumpeter insisted that Marx was mistaken on this point. The premise that this process would simply persist at an “even rate” was flawed (Schumpeter 2003, 40); market conditions and social realities would create changes that could absorb or transform the very conditions Marx rested his conclusions upon. Instead, precisely that “revolutionising of production” would ensure its continuation, as the many cycles intrinsic to the life of capitalist production and the market society would, despite temporary ‘crises’ of repressions and depressions etc., absorb tendencies to go too far in one direction, whether it be monopolization, massive unemployment, overproduction, etc. (Schumpeter 2003). Consequently, at least for a significantly longer time than orthodox Marxists allowed, the capitalist social order would in fact avoid the ‘trap’ Marx argued, and perhaps hoped, it would spring upon itself, in large part by virtue of the innovative processes of creative destruction intrinsic to it.

"Creative destruction" is a complex term with a contested genealogy and a rich life that cannot be extensively analyzed here. Its importance to this study lies not in its author's specific uses of and conclusions drawn from its theoretical matrix, but more in the way it was taken up by and influenced both neoliberal economists increasingly centering an emerging notion of information in their theories, and a nascent culture of a rapidly developing computing industry that would soon grow infatuated with a related libertarian ethos. This confluence would ultimately create the conditions for "disruption" and "revolutionary" ideation to become the omnipresent, magical chorus of Silicon Valley venture oligarchs and their epigones, and so unfold into a more general socio-cultural usage, dominant in the sense of Raymond Williams' schemata for structures of feeling: an omnipresent and questionless cultural element in business and tech-speak.

Creative destruction and Schumpeter's work in general were invested in the notion *innovation* as an economic concept, a term that his work helped popularize in the latter half of the 20th century. It's easy to see why: "innovation" is a word that at least in part is useful for succinctly naming the "constant revolutionizing of production." For Schumpeter and those that carried the banner of creative destruction into the inchoate barony of Silicon Valley, *innovation* did (and does) not simply indicate the process of introducing novelties, or the renewing/making new of some existing thing. In this context, an innovation is, basically, an invention that is made *newly valuable*, generally defined in terms of a thing that becomes newly commercially successful. In other words, innovation is what fuels and is propelled by Schumpeter's famous wind/hot air/gale. Innovation is the wave that lifts and delivers capitalism from its own self-destruction and carries it into the future, the engine that perpetuates the capitalist order by saving it from itself, no matter how painful to the businesses and institutions subjected to this creative violence, necessary sacrifices on the altar of efficiency and progress that they are.

Innovation provides a key link between Schumpeter and the rise of techno-utopian, digital libertarians that have championed "disruption" and made revolution a by-word catchall for all of the above; and, therefore, to the rhetoric of revolutionary disruption shot through precision agriculture discourse. This link has been studied from a variety of perspectives in a number of significant works, including in Fred Turner's *From Cyberculture to Counterculture* (2006), Philip Mirowski's *Machine Dreams* (2002). In the latter, Mirowski offers a critical account of how "Economics Becomes a Cyborg Science" that depicts the confluence of neoliberal economics and information through the linkage of John von Neumann's work with that of major economists like Friedrich Hayek and Schumpeter during the first half of the 20th century. This confluence contributed to the emergence of an influential reconceptualization of economics in informatic terms, and of markets and the individual economic agent itself as first and foremost information processors; in tandem, the development of computers and information theory offered new ways in which to develop and extend this concept.

By the latter half of the 20th century, as Turner (2006) and others have shown, an emergent countercultural libertarianism, grounded in an epistemo-ontological substructure of cybernetic theory, had grown and spread within the computer industry. At once intellectually rooted in the new, information-centric economic philosophies, the political mythologies of epic self-creating individuals like those offered by Ayn Rand, and the temple of innovative creative-destruction that sat in the middle of the Venn diagram these formed, by the 1990s this culture and industry were especially well primed to seize upon Clayton Christensen's new business theory – "disruptive innovation" – and run with it.

Disruption in the contemporary sense is derived from the concept of "disruptive innovations," famously defined in Harvard economist Clayton Christensen's 1997 book *The Innovator's Dilemma*. Disruptive innovation presented a theory of why well-established businesses can be toppled by insurgent startups. Originally, Christensen's *disruption* was a relatively specific concept, meant to highlight the dangers of successful companies' rational myopias – focusing on profitable customers and missing important shifts in consumer zeitgeist. But *disruption's* genealogical substrate reaches into the older and more primary earth of creative destruction. Historically and culturally, *disruption*'s wild popularity and rapid saturation of US business and tech culture more generally owes as much or more to its situation at the crux of two deeply influential and ultimately insinuated developments noted above: the birth of modern computing, cybernetics and information theory on one hand, and the development and spread of neoliberal political-economic theory on the other (Cf. Mirowski and Plehwe, 2009). Turner (2006) details how in the general American imaginary, computers transformed from ominous and coldly authoritarian military machines of the 1950s into liberatory equipment for living by the 1960s at the hands of an influential movement of countercultural individualists – anti-authority libertarians enthralled by the emerging ideology of cybernetics like Stuart Brand, and later Steve Jobs, Bill Gates, and Kevin Kelly. These counterculturalists and digital entrepreneurs came to view computational technologies as tools for deliverance from grey flannel institutionalism beginning in the 1960s, technologies that would throw off the fetters of both creativity and government regulation (Turner 2006; Kline 2015).

During a roughly similar postwar period, influential members of the Mt. Pèlerin Society (established in 1947) like Friedrich Hayek, and high-profile scholars located in the Chicago School of Economics – including Milton Friedman and later Richard Posner – worked to dethrone the dominant statist Keynesianism of the postwar West, developing economic philosophies encouraging economic decentralization, market de(re)regulation, and ICT-dependent global free trade systems deeply indebted to cybernetics and information theory (Harvey 2005; Mirowski and Plehwe 2009). In many ways remarkably different, the rhetoric, prescriptions and worldviews of these counterculturalists and establishment economists came to inflect or resemble one another through a shared faith in information flows and self-regulating systems as the path to greater freedom and liberty. This often avowedly "apolitical" marriage of individualist entrepreneurialism to a radical free-market evangelism was founded on an essentially epistemological belief in the power of information and computing to reveal truths in greater accord with "nature" and "natural laws"; specifically, a faith in their ability produce new insights, opportunities, and efficiencies in all walks of life (Cf. Harcourt 2011; Invisible Committee 2014). Released from their statist-military origins and put in service to free trade, computers and databanks would produce the rational world of peace, opulence and liberty that political struggle had so frequently and catastrophically failed to deliver.

The marriage of informatic ontology to hypercapitalist libertarianism has significantly shaped contemporary politics, business, and social life as such since at least the 1970s (Hayles 1999; Turner 2006; Crary 2014). Cybernetics and information theory inform environmentalists and extractive capitalists alike – they are as integral to the birth of ecosystems thought and neo-Malthusianist anxieties about overpopulation as identity marketing and cryptocurrency. The success of *disruption* as a motive, explanatory concept and referential cornerstone was predicated on this broader, more fundamental spread of a digital-economic mythos across both the sciences and humanities. It has also, not without some irony, led to its own institutionalization as a core concept of business education and commercial rhetoric (Lepore 2014).

As noted in Chapter 1's discussion of *precision* and the influential migration of martial command & control rhetoric into digital business discourse, one socio-cultural product of today's now conventional and generalized "disruption" or "disruptive innovation" is a tendency to re-christen computerized innovations of existing technologies as "smart" version of its predecessor. Usually marketed as a "reinvention," "transformation," or "revolutionary," this rhetoric is often comically banal in its application to mundanities like sprinkler systems, thermostats, or pet food dispensers, let alone the mincing iterative developments in marketing APIs or database management software also characterized this way. Here the appellative-adjectives "smart" and "disruptive" proxy for an implied mediation or connectivity, some type of predictive or adaptive function that will inform management or "decision-making" in whatever innovative, miraculously useful way.

Given this history, it is perhaps unsurprising to find datafication, automation, and machine learning – the birth of the data farm, and smart farming – offered as solutions to a looming socio-enviro-agricultural crisis in precisely this idiom. The discursive framework organizing precision agriculture will be eminently familiar to STS and Media Studies scholars, as it is similar in substance to myriad other practices, phenomena, arts, and objects subject to the technopolitical gospel of disruption, from medicine, to labor, to the work of culture itself (e.g. Chiu 2011; Hallinan and Striphas 2014; Scannell 2015; Medina 2015; Levy 2015; Cubitt 2017). That is, for all the romantic power it holds for business school graduates and digital venture capitalists, *disruption* – whether in its explicitly limited definition as a successful commercial upstart, as an ancestor of Joseph Schumpeter's theory of *creative destruction,* or in terms of its broader cultural diffusion as a species of *innovation* – is never "revolutionary" in any meaningful sense. This is especially true when it comes to conventional market-oriented farming systems.

On their face, claims for precision agriculture's revolutionary character do not commonly rest on the argument that they portend fundamental political or economic upheaval in, say, a Marxist sense. Rather, industrialists, journalists and technologists frame it as disruptive insofar as it provides novel, "better" ways of knowing and doing agriculture, in line with the tropes of techno-determinist theories of an ontologically profound Fourth Industrial Revolution (e.g. Floridi 2014; Shwab 2015). These theories tend to portray expanding frontiers of a flattening, generalizable information-based ontology – a world where everything can be rendered into/as information, and so placed upon a universal and equivalent ontological tableau, infinitely fungible, interchangeable, and computable – whose key agents are digitization and datafication, and of which therefore precision agriculture constitutes a significant, if late-coming part. Much like the original Green Revolution, however, while precision agriculture advocates rarely describe its revolutionary character in explicitly political or economic terms, the implications are often just under the surface – especially where PA is incorporated into the conflated with the social transformations those advocates claim are driven *by* information technology. It's worth remembering that the Green Revolution was so named for explicitly *not* being a Red Revolution. That is, for framing the phenomena of hunger and dearth as a series of technical challenges to be solved by (exceptional, individual, White, Male, Straight, Physio/Neuro-typical, Western) scientists and leaders, rather than as fundamentally political problems created by gendered, classed, and racialized issues of land distribution, labor appropriation, and food production for a neo-liberalizing global commodities market, among others (Patel, 2007). By working within the confines of a "revolutionary" apparatus that leaves unquestioned the core economic and political structures of liberal capitalism, precision agriculture seeks to extend a system of ecologically exploitative *in*efficiency – what Jason Moore (2017) calls the appropriation of "Cheap Nature" – that more than any other activity has contributed to the looming spectre of environmental catastrophe in the first place.[20] In this respect, then, and despite appearances to the contrary, avowing a disruptive precision agriculture revolution is to express allegiance to an ardently political, economic programme, insofar as that programme is explicitly designed to leave the dominant material-symbolic orders of conventional farming intact.

For the overwhelming majority of stakeholders I have interviewed involved in the agriculture industry and the emerging precision farming trade, the implementation of precision agriculture systems is a completely logical, if in *some* respects "radical," next step for their industry. And this is the point – it *does* "makes sense" when one's operating perspective is one that both perceives and is beholden to 'the market' and its 'forces' as the most rational, efficient, and ultimately natural means for organizing food production.

This is the "distribution of the sensible" in action, in which precision agriculture as revolutionary disruption operates as a part of what Jacques Rancière names "police:" the form of proscriptive semiotic and material ordering of discourse and imaginaries that takes dominant/normative conceptual and material frameworks as presumptive universals and questionless givens (Rancière 2010; more on this in the following chapter). If there is concern about the environment, about animal welfare, or about the farming system in general, these are consumer concerns, technical problems to be solved by expertise and authority, not irreducible political antagonisms stemming from hostile or differential forms-of-life and ways of being (see

[20] Or, as Michel Foucault put it: "there are many different kinds of revolution, roughly speaking, as many kinds as there are possible subversive recodifications of power relations … one can perfectly well conceive of revolutions that leave essentially untouched the power relations that form the basis for the functioning of the state." (Foucault 1980, 122-23)

also Mouffe 2009). Thus the normative questions guiding the design choices of precision agriculture technologies are never 'why is it possible to render and biologically reshape cows as cattle/capital,' 'what are the conditions that license migrant and itinerant farm workers to exist in such legal exposure and bodily precarity on US farms and in slaughterhouses,' or 'why do we need to produce more food, more intensively/how is it so many people can be so persistently hungry when 40% of all food produced in the United States per year is already discarded?' The question is, rather, 'how can we increase profitability on a 3000 acre corn farm at carrying capacity by more than 2% annually with more efficient algorithms, and value-add with data-driven supply chain transparency programs?'

In precision agriculture discourse the lay of the land is never fundamentally in question, a form of scientific and agricultural "selective ignorance" in the sense outlined by Kevin Elliot (2012). Indeed, the lay of the land most favorable to the production of commodities for the market is the explicit precondition of precision farming, insofar as the distribution of the sensible in this case is the literal plowing of a field. That's to say, precision agriculture is of less value or utility on varied terrains, among smaller farms, on farms using alternative methods – anywhere there is a failure to organize the crops, ground, surrounding life and environment, and indeed one's agricultural concern in general in a way that is available, adaptable, or usefully legible to the digital sensors and data programs employed in precision agriculture. In order to grow billions of bushels of near-identical commodity crops in the intensive, high-efficiency context required for profitable conventional farming, the earth must be cleared, ordered, treated, mapped, surveilled, chemically shrouded, and generally ordered into a kind of biological desert. Furthermore, precision agriculture systems which assume such a foundation, are optimized through both private and public research programs to deal with the specific, quantifiable properties of a handful of plant and animals species of that milieu.

That is, precision agriculture as full spectrum dominance of the land requires as its condition of possibility that there are already “rows upon militant rows of corn” to function (Gaalaas-Mullaney 2015) – civilized, tamed, domestic and ordered; an imperialized unwild. At present, a precision combine has no truck with unconventional forms of agriculture that are more insinuated with the diverse species of their actual ecological tableau, like the small-scale maize growing practices in the central Mexican highlands which are similarly insensate to a multi-spectral UAV – they cannot parse such bio-topographical diversity (Gaalaas-Mullaney 2015). When confronted by the disembodied, clinical rhetoric of “revolutionary” precision and disruptive innovation, whether under the mantle of “signature” drone attacks in the so-called War on Terror or the abstracted informatic ontologies of digital agriculture, bearing in mind the fact that *the ground is always in play*, as Madiha Tahir (2016) has urged, can help reorient our attention away from the techno-fetishism of disruption back towards the people, land, animals, plants – and intentions – behind and underneath the tools.

iii. The Informatic Ideal

If precision agriculture is not, as I contend above, a revolutionary transformation, but it does represent a change in agriculture, what does that mean? How can both be true? Instead of grasping the digitization of farming through the eyes of its financiers and the tongue of its partisans, as epistemological herald of the house of disruption, the 4th industrial epoch of its name, precision agriculture can be better understood in terms of an emerging “structure of feeling” in the idiom of Raymond Williams, a broad social and historical complex of differentially related and unevenly unfolding socio-technical processes. Or, in a word, an "ideal." This ideal, which is at once social and technical, ideological and material, has particular cohering characteristics that can be named, and a common genealogy that can be described. Its emergence and spread represents without qualification real, significant, substantial changes, plural, in the industrial state and socio-technical reality of contemporary agriculture. But there is change, and there is "change."

In my home city of Syracuse, NY, an increasingly hostile debate over the future of Interstate 81, the main arterial raised highway running North-South through the center of the city, currently rages. The highway is ancient in infrastructural terms, has a fraught and ignominious history of racist dispossession and urban blight, and has reached an inflection point in its social and material life: it must be torn down and either rebuilt as is, or replaced with some new system. Things cannot stay the same without the highway simply collapsing. The debate is over whether to simply reproduce I-81 as it currently exists, and with it all the extant harms and inequities, affordances and limitations it perpetuates, or to completely re-imagine and re-develop the very heart of our city through a process that would involve expanding the criteria for conceiving of and involving the stakeholders of our region affected by the highway, stakeholders who would then partake of and exercise real political power in the decision-making and planning process. This path would represent a true change – e.g. in the very conception of the political reality of our city – by way of a change in the infrastructural reality of our city. Tearing down and rebuilding the entire structure *also* represents a complete and total transformation of its material reality, that would have undeniable effects, and would certainly involve re-design and new features. But this is not change by any meaningful definition; the thing itself would remain, and continue to produce the effects it has for the past 70 years. This is revolution as spinning-in-place. So, I contend, is the existing socio-technical imaginary that motivates, organizes, and impels the digitization of conventional agriculture in order to shore up the extant social, political, and ecological order that convention names. What I call the informatic ideal is the shape that discourse currently takes.

Broadly speaking, the epistemological confluence of neoliberal economics, information theory/cybernetics, and faith in ahistorical, techno-determinist grand narratives outlined in the previous section represent part of this emergent structure of feeling: what, after Deborah Fitzgerald's notion of the "industrial ideal" of farming, (2003) I call the "informatic ideal" in agriculture. A key object and characteristic of the informatic ideal in agriculture is that of cybernetic "control" by a particular definition – related to that touched on in Chapters 1 and 2, and what I will describe and expand upon as "code as law as *police des grains"* in the following chapter. I understand control here in the sense first elaborated by Gilles Deleuze across a series of texts in the late 20th century (1992; 1995; 1998; 1999), and recently further developed by Franklin as a cultural logic of "digitality" (2016): namely, an influential discourse or "logic under which social [and cultural, biological, physical, et al.] worlds are reconceptualized as information-processing systems" (2016, xv). This ideal is ultimately a kind of algorithmic, which is to say computational, expression of a more fundamental industrial rationalism and informatic control intrinsic to capitalism and the socio-technical relations it fosters. The informatic ideal is no more reducible to computerization as the industrial ideal is to mechanization. These emblematic technologies, which are without question deeply insinuated with these ideals and forms, are better understood as expressing and co-producing "the social forms capable of producing them and making use of them" (Deleuze 1992, 6). This claim requires some elaboration, which I will offer below, followed by a description of the main characteristics of the "informatic ideal" in contemporary agriculture.

Popularly, informatic, computational control is most immediately derived from the confluence of several well-known techno-scientific developments prior to, during, and after World War II in the United States and United Kingdom. To name but a few: Alan Turing's description of an idealized computation machine; the invention of electronic digital computers during the War; the simultaneous publication of Norbert Weiner's theory of cybernetics and Claude Shannon's "A Mathematical Theory of Communication" in 1948; the rapid spread and influence of both of these concepts across the academic and intellectual world via the Macy Conferences, and so on (on this history, esp. its socio-cultural dimensions, see Kline 2015). Some scholars of information, such as Gleick (2012) and Beniger (1989) go further than this popular account, correctly intuiting the deeper historical roots of informatic control. Yet these authors make the mistake of naturalizing and essentializing the phenomena of information and control, veering into hagiography and ultimately producing deeply ahistorical histories of their subjects. To their credit, they are hardly alone. As Peter Janich explains, the dominant conception of information and related notions like cybernetics and control are centerpieces in a significant "scientific myth" of our time – that information is a "natural object" – a myth "that has for a long time now left the sciences behind and become part of daily life" (2006, 1).

In Janich's account, this myth is a product of a failure, the "naturalization of information" in which information is advanced as an ahistorical, elemental component of physics (physics as a science; *physi*s as nature), and so a constituent of the physical universe, a position summarized by Norbert Wiener's assertion that "information is information, not matter or energy" (2006, 4). Biology, genetics, neuroscience, life itself become reinterpreted through and as informatic code, with “code” and related idioms and apparatuses of media and communications techne playing a central semiotic role in the production of informatic equivalences across disciplines (it is no accident that among the most common scholarly acronym for designating “digital/computational technologies” is “ICT” – “information and communication technologies”). This influential information mythos also famously spread into areas outside of the “hard” sciences into the social, however, from anthropology and linguistics (Geoghegan 2011) to political science (Deutsch 1953; Light 2004), economics (Mirowski 2002), and critical scholarship of science, technology and media (Galison 1994; Edwards 1997; Kittler 2012) to name only a few. This dissemination and take-up of information theory and cybernetics outside of their initial disciplines unfolded for a variety of complex reasons; critically however, as these spread so did their discursive, epistemological trappings. Defined as a physical constituent of existence itself, information theory catalyzed sometimes dramatic idiomatic, epistemological, and ontological transformations in the fields it touched or helped found. Franklin (2015) summarizes this “logic of control as episteme” –the root of the informatic ideal – as a

> wholesale reconceptualization of the human and of social interaction under the assumption—visible in … the dominant social, economic, and political practices of the present—[which contends] that information storage, processing, and transmission (as well as associated concepts such as “steering” and “programming”) not only constitute the fundamental processes of biological and social life but can be instrumentalized to both model and direct the functional entirety of such forms of life. (xviii)

As Tiqqun explain in *The Cybernetic Hypothesis*, informatic/cybernetic epistemology

> …effectively implements, at the start, [an] identity between life, thought, and language. This radical Monism is based on an analogy between the notions of information and energy. Wiener introduced it by grafting onto his discourse the discourse of 19th century thermodynamics; the operation consisted in comparing the effect of time on an energy system with the effect of time on an information system. A system, to the extent that it is a system, is never pure and perfect: there is a degradation of its energy to the extent that it undergoes exchanges, in the same way as information degrades as it is circulated around. This is what Clausius called entropy. Entropy, considered as a natural law, is the cybernetician's Hell. It explains the decomposition of life, disequilibrium in economy, the dissolution of social bonds, decadence... Initially, speculatively, cybernetics claimed that it had thus opened up a common ground on which it would be possible to carry out the unification of the natural and human sciences (2001, 15).[21]

[21] I would simply add that Satan, not Hell, would be the more appropriate analogy here – hence Maxwell’s “demon”.

Accordingly, the conventional origin story of information outlined above obscures more than it explains, and lays the causality of the apparatus of informatic control's genesis at the feet of techno-scientific invention, when quite the opposite is the case. The techniques and technologies normally associated with control – computers, electronic communications media, and information technology broadly defined – did and do not create this episteme, they were and remain the expressions of a far older socio-economic logic that sought to produce and achieve the arts of government, good order, and political economy. The use of information technology as devices of control are more accurately and fundamentally understood as products of a "diffusion or atomization of the logic of capital" (Franklin 2015, 6).

While more on this historical entanglement and co-production of information, control, capitalism and governmentality will be covered in Chapter 4, here we can at least outline a few core relevant historical points and key characteristics of the informatic ideal before proceeding to describe its manifestation in agriculture.

As I noted above, I have explicitly modeled and developed the concept of an informatic ideal after Deborah Fitzgerald's (2003) fundamental work on the introduction of an "industrial ideal" to American agriculture during the early 20th century. Where Fitzgerald's work highlights the introduction of the rationalized factory form and Taylorism to farming, this thesis describes an extension, intensification, and transformation in this earlier foundation rooted in cybernetics, computing, and information technologies. Instead of precision agriculture as a "revolutionary" development, I contend that what is in fact unfolding in the digitization of farming is a process rooted in, and resonant with, that described in *Every Farm a Factory*. In other words, both concepts are intended to signify important changes in the technics, technologies, and conception of agriculture related to the emergence of an influential new body of discourses, socio-technical systems, and socio-environmental conditions. The contemporary process of digitization, I contend, is no more 'revolutionary' in any meaningful sense than the previous process of industrialization, insofar as both are understood here as socio-economic phenomena stemming from and propelled by the capitalist market imperatives to constantly increase efficiency and productivity in order to produce the growth necessary for profitability and the reinvestment of that (surplus) profit into the means of production.

Fitzgerald's book as a whole serves as a kind of thick description of the industrial ideal she carefully describes, making it difficult to summarize her definition without undue losses. The closest she herself comes is perhaps in this introductory passage, explaining what previous accounts of agricultural industrialization have missed. For Fitzgerald, this "industrial logic or ideal" at the heart of agricultural change was

> epitomized by the modern mass production factory and industrial boardroom, [which] linked capital, raw materials, transportation networks, communication systems, and newly trained technical experts. Interconnected and often sprawling, these systems of production and consumption functioned like grids into which fit the more identifiable components of industrialization—the tractors, paved roads, bank credit, migrant labor, and commodity markets. (2003, 3).

The introduction of an industrial ideal into American agriculture was grounded in the belief, held by influential elites spanning business, government, finance, research institutions, and the agricultural industry, that "agriculture should modernize in just the same way as modern factories and business enterprises," with companies like Ford serving as privileged examples (6). This meant adopting principles and techniques "drawn directly from…factories and businesses" to agriculture, things like "timeliness of operations, large-scale production sites, mechanization, standardization of product, specialization, speed of throughput, routinization of the workforce, and a belief that success was based first and foremost upon a notion of "efficiency" (6).

Fitzgerald argues that rationalization initiatives and the mechanization of agriculture that crystalized and rose to dominance in the 1920s should be considered "industrial" in nature for several reasons. These include the fact that significant agricultural sectors like CAFO-based cattle, pig, and chicken husbandry explicitly transitioned to the factory form; the adaptation of the assembly line form to a static product – crops in a field – in which "the product is stationary and the humans and machines move;" the importance of quantification, including of time and labor; the organization of unions in the farm sector; and the fundamental transformation of agricultural crops into mass produced, fungible, equivalent and graded commodities "poured into sacks … and shipped out across the country" ala Cronon's discussion in *Nature's Metropolis* (Fitzgerald 2003, 4).

Similarly, the centrality of "technological and scientific innovations" to these changes in agriculture also bespeak this industrial character, both in terms of the new machines and technologies like "tractors, hybrid seeds, pesticides, electrification" and so on, and the "matrix of technical, social, and ideological relationships that both created and sustained" such technologies. Each depended on whole complexes of other technologies, institutions, systems, relationships, and processes that themselves contributed to the spread and acceleration of agricultural industrialization: "When a farmer adopted a tractor, for example, he tacitly adopted a whole host of other practices and entered into a new set of relationships" (Fitzgerald 2003, 5).

The informatic ideal is similarly grounded in a belief, held by influential elites spanning businesses, government offices, finance, research institutions, and the agricultural industry, that agriculture should modernize on the model of Silicon Valley, with companies like Google or Apple as examples. This reality was explicitly highlighted in one of the earliest interviews I conducted for this project. In 2017 I spoke with a member of a farming family with a large farm in Western New York about his family's farm, and his views on the roles he and his peers would play in the future of agriculture. At that time, he was an undergraduate at Cornell University taking courses in both Electrical and Computer Engineering and the SUNY College of Agriculture and Life Sciences. While discussing his chosen major and the qualifications that future farmers will need to stay in the business, particularly in light of companies like John Deere's interests in keeping its code "locked tight" with IP protections, this interlocutor, sensing I might not grasp the actually existing reality of the industry, pointed out that Deere was not seeking to be *like* Silicon Valley, but that "Deere *is* Silicon Valley."

He went on to explain that he'd had opportunities to visit and tour companies like Tesla and the "Googleplex" through connections with Cornell. Later, on walking into Deere's Moline, Illinois headquarters for an interview, he told me he was immediately struck by the fact that, for all intents and purposes, Deere and Tesla are "one in the same. They've got the same office layout, physically they [Deere] are mimicking the Silicon Valley companies … I walked into the [Deere] world headquarters and it felt like being in Google." He stressed that the similarities were not simply aesthetic; he observed implementation of the "same exact management style that you'd see [in Silicon Valley]" as well. Established agricultural companies, in other words, are today not simply producing increasingly computerized versions of extant technologies, be they tractors or seeds – they are culturally, aesthetically, and technically adopting the methods, materials, and idiom of Silicon Valley itself.

Digitization and automation initiatives in agriculture that have emerged and crystallized over the past 30 years should be considered "informatic" in nature for several reasons, many of the technical and methodological reasons for which are discussed at length in Chapter 2. These include the widespread mediation and computerization of existing means of production, from tractors and farm buildings to offices and operational logistics, as well as efforts to render the bodies, life, and lives of flora and fauna transparent, trackable, and controllable in more complete and exacting ways made possible by digital media is a clear extension and intensification of the same logic that underwrote the development of CAFOs as a technology of industrial slaughter, hybrid genetics, and monocropping in the first instance. What Fitzgerald describes as the inversion of the assembly line model in industrial farming, and what Goodman, Sorj, and Wilkinson call "appropriationism" (1987), is again in the computerization of farm technology not so much broken with through an epochal shift away from the present order of things, as pointedly escalated and doubled-down upon through the use of more powerful and granular C4I technologies. All this is without even considering the figure of precision agriculture's twin or obverse, the increasingly popular indoor, urban, hydroponic factories currently studied by my colleague Dan Quarooni. Such operations aim at finally achieving what the facts of agriculture's material, practical reality always made difficult, if not impossible, e.g. conforming the production of food commodities to a non-inverted industrial production system in literal enclosed, soil-less factories.

Data and quantification have only grown exponentially in importance following the advent of the informatic ideal in farming, including not only far more extensive surveillance and record-keeping of time and labor, but whole new axes and classes of increasingly granular information, examples of which are detailed at length in Chapter 2. Relatedly, the reorganization of crops around a logic of fungibility, exchange, and flow characteristic of capitalist rationalization and industrialization of agriculture has, in the informatic image of the precision agriculture data farm, only exploded in importance and dramatically intensified the roles of commodity gradation, standardization, and other forms of quantified equivalence. This is true not only of agricultural products themselves, but increasingly of the data about that produce and of farm operations; for farmer-owners, for the companies that sell and service the digital technologies used to generated and manage that information, and for state institutions and agri-food corporations that seek to use this waxing surge of agricultural data towards regulatory and commercial ends.

Finally, where "technological and scientific innovations" were central to the advent of agricultural industrialization, the same can easily and obviously be said of agricultural digitization. New machines and technologies like computers, digital media and communications technologies, remote and proximate sensing, automation, drones, dramatically advanced genetic manipulation techniques, "internetification" initiatives, like electrification schemes before them, designed to bring broadband to un- or under-serviced rural areas bespeak the informatic character of precision agriculture, as well as the "matrix of technical, social, and ideological relationships" that both create and sustain them. No less than the new combines, hybrid seeds, and monocropping techniques of the industrial ideal, these technologies also depend on complexes of related technical systems, institutions, relationships, and socio-technical infrastructures. To borrow Fitzgerald's formula, when a farmer adopts a drone, for example, they tacitly adopt a whole host of other practices and enter into a new set of relationships.

The point of relating the industrial to the informatic ideal in the way I have here is not simply to illustrate that the processes of technological change and socio-technical innovation resemble one another schematically, given shared contexts of capitalist imperatives, market societies, and dominant liberal state forms – indeed, the same analogies would be easy enough to make with any other industry or technological development in agriculture if so. The point in foregrounding that resemblance and the contexts and conditions that produced it is to illustrate the clear continuity and continuation of a specific social logic through what we might call superstructural transformations on a shared substructural basis.

In sum, the socio-cultural logic of information that manifests as the "informatic ideal" is most immediately a product of an ontological collapse of being into informatic equivalence, mediated as and by information, which itself historically comes to be portrayed as the 'medium that can become all other media' in the form of electronic digital computers (Vismann and Krajewski 2008, 91). But the informatic ideal does not derive from these latter 20th century developments alone, as the birth of cybernetic information and the logic of control in and of themselves were predicated on, informed by, and developed out of preexisting historical phenomena institutions, apparatuses, and discourses whose origins can in many respects be traced back to the 15th – 18th centuries. These include the often entangled and co-productive development of 1. increasingly centralizing European states, empires, and militaries and/as the various apparatuses of government that developed with these, from cameralism to the "police sciences" of administration to political œconomy and government itself; 2. the birth of capitalism and inauguration of the "market society" (Polanyi 2001); 3. the development of classical economics and liberalism, 4. Techno-scientific developments in thermodynamics, media and communications, and information technology, among others. Each of these historical processes contributed to increasingly powerful needs, imperatives, and conditions for rationalization, order, visibility, and control, spurring in turn the development of technologies of bureaucracy and management, measurement and quantification, manufacture and machinery. This is the history out of which grew both the industrial and informatic ideals in agriculture, which, as I argue below, are ultimately different elements of a shared genealogy – that of "conventional" farming.

III. Algorithmic Rationality – a genealogy of convention

Information technology has authorized precision agriculture in two ways. The first follows from the sense in which what is called modernity may itself be understood as intrinsically algorithmic. This is what we might variously describe as an informatic, computational, digital, or algorithmic rationality underlying the modern world: a mechanical reorganization of industry and reasoning upon rule-based grounds, fueled by the emergence of capitalism and the liberal nation-state. The second owes to emergent shifts in the connotations of *algorithm* over the past decade, discourses of big data, artificial intelligence, and computation as effective and democratic (Striphas, 2016). This is a phenomenon at the core of the informatic ideal: a fetishization of information that ascribes super-natural powers of divination and agency to digital technology (cf. Chun 2011). Unpacking what I mean by *algorithmic* in these two ways will illustrate how, far from representing a revolutionary break, precision agriculture is better understood as part of a general intensification or evolution of long-established social and economic systems characterized by rationalization, accumulation, and control rooted in capitalism and the liberal nation-state.

Algorithms were for centuries the exclusive domain of mathematicians. Beginning in the later 18th century, however, they grew rapidly in significance; by the end of the 20th they constituted an entire branch of mathematical theory (Daston 2010; Striphas 2016). The events that contributed to these changes in *algorithm's* uses also helped redefine the word itself, gradually leading to an association of *algorithms* with systems of rules. What changed algorithmic *techne* from a highly specialized domain of mathematics during the 18th century, to a widely celebrated and increasingly universal logic organizing such disparate social, cultural, and political phenomena by the 20th?

In short, rationalization – first of physical, and later, mental tasks. Daston (1994; 2010) and Erickson et al. (2013) trace this process across an epistemological shift from dominant intellectual discourses of Enlightenment *reason*, to a rule-based algorithmic rationality: “a finite, well-defined set of rules to be applied unambiguously in specified settings” (Erickson et al., 2013: p. 26). While Enlightenment reason and modern rationality have much in common, e.g. an emphasis on risk, utility, and formal procedure, they rest on fairly distinct epistemological foundations. Reasoning is an act of judgment, and so demands wisdom, deliberation, and positioned subjectivity; it carries the potential for disagreement and uncertainty. Rules and rationalization are by contrast clearly defined, quantitative, and designed to be universal and conclusive. Where reason implies embodied history, rationality aspires to abstract, functional, transposable, and inherently rule-bound parameters (Erickson 2013).

Totaro and Ninno’s (2014; 2016) frame the transition to modern rationality from medieval, reason-based epistemologies in terms of a move from *substance* to *function*.[22] They argue that rationality is algorithmic, algorithms are recursive functions, and that while rationality broke from the sphere of mathematics and ‘invaded’ the fabric of everyday life over the 19th and 20th centuries, rationality *qua* algorithms remain essentially beholden to a numerical logic that is incommensurate with the incalculable continuums of the actual, everyday world. Here “substance” implies the Aristotelian essentialisms of medieval thought, as opposed to the inherently relational values of mathematical “functions,” a “variable quantity regarded in relation

[22] The historical change in the meaning of *information* from force that shapes to a quantity offers an instructive example here. Until roughly the 18th century, information belonged to an essentialist philosophy of being, and described the ways in which essence manifested itself in matter; to inform was to lend something its shape, to express its substance (Peters, 1988). By the 20th century, information had been denuded of its Aristotelean trappings, and served instead as a metric, a mathematically defined measure of “difference” in the theories of Claude Shannon and Norbert Weiner. Difference, of course, is purely relational: where it had once lent form to substance, it was now both a literal and figurative function, a measure of a variable defined in relation to other variables.

to a variable or variables upon which its value depends" ("function".n.). For Totaro and Ninno, both physical machines and abstract algorithms involve a general form of calculability apprehendable in terms of recursive functions – a set of operations that repetitively operate on themselves, i.e. the circular action of a gear. The kinship between the mechanical and the algorithmic lies in the fact that not only do "all machines run an algorithm," but "one can say [machines] are the materialization of an algorithm, which in itself is a logical object" (2014, 32). As the world became more mechanical, it necessarily grew more algorithmic.

But what precipitated this invasion? The birth of an algorithmic modernity did not simply follow from the mechanization of industry. Rather, as Marx made clear, mechanization followed more primary transformations in economic activity, and philosophically formalized, rule-defined procedures for manufacturing goods or managing bureaucracies that transformed human thought and activities (Marx 1976, 455-470).

By the time Adam Smith published *The Wealth of Nations* in 1776, a capitalist world-economic system had already been growing for over 200 years (Smith 1981; Wood 2017). Its spread was instrumental to the transition from a medieval ontology attuned to substances and essence (e.g. coins as intrinsically valuable owing to the metal of their mint), to inherently relational systems of commodities, valuation, capital, and money (e.g. coins, paper money, credit as symbolically – i.e. relatively-functionally – valuable). Unlike the essentialist, strictly hierarchical foundations of theocratic monarchism and feudal organization of production, capitalism was and remains ontologically functionalist, quantitative, and rational (one should not forget the basic relationality of *ratios* living in *ratio*nalism). Capitalist production depends absolutely on a flowing, relational character of commodities, the functional nature of capital, and the rational organization of manufacturing. This more properly functionalist, rule-based organization of production gradually established its incommensurability with earlier or alternative ways of knowing, living, or producing, gradually reorganized economic and political systems around its logic, and lent growing material force to 18th century liberal critiques of divine political authority and economic paternalism.

Smith's genius partly lay in his ability to synthesize these developments with breadth, insight, and a proclivity for arresting examples. His intervention in debates between Physiocratic beliefs in natural order and Cameralist "political œconomy" over the 17th century helped popularize a new economic model in closer accord with the rationality of bourgeois capital (Harcourt 2011). His (in)famous fable of the pin-factory is notable both for capturing a historical transition in action – the emerging logics of industrial rationality incentivized by capitalist relations and the production of commodities – and for providing a pithy, persuasive account of that emergent rationality. Take the work of a skilled craftsman, break it into tasks, break those into discrete steps, assign those steps to unskilled individual workers, and so increase the efficiency of producing both commodities and profit. Smith succinctly captured the mechanization of labor (which is to say, *laborers*), i.e. the rationalization of production into algorithmic, recursive processes, necessary before actual machines became common on the factory floor.

Like most crafts, farming was compelled to adopt industrialization, but unevenly. Because agriculture's object is the land and life itself, a vast complex of natural forces resistant to easy rationalization, it took comparatively longer than in other industries amenable to factory production (e.g. textiles or iron milling) to introduce the same degrees of rationalization and mechanization (Goodman, Sorj and Wilkinson 1987). One important early step towards greater rationalization and commodification was the introduction of common standards for grain, futures markets for their harvest, and the regulation of these through the Chicago Board of Trade in the mid-1800s (Cronon 1991). These regimes not only encouraged mass production of interchangeable wheat, they helped make farmers themselves effectively "fungible" commodities, in that standardized grades allowed produce be assessed independently of the farm or farmer it came from. Where previously an important organizing logic of distribution and marketing was reputation ('farmer Tom grows excellent corn, and so it fetches a higher price'); standardization essentially rendered all crops or products equivalent within a grade ('Class 1 drinkable milk fetches a higher price than Class 3 cheese milk') (cf. Harcourt 2011).

Similarly, a series of government acts over the 19th century were critical for developing more uniform, rationalized approaches to farming. The 1862 Morrill Land-Grant Act established agricultural research colleges across the US, the 1887 Hatch Act funded new experiment stations at those colleges, and the 1914 Smith-Lever Act created the US Extension Service for the public distribution of agricultural research. Together, these acts laid down the basic techno-scientific infrastructure needed to make "every farm a factory" (Fitzgerald 2003). During the 1910s and 1920s, agricultural engineers helped spread an industrial ideal among farmers, while promoting tractors, electrification, pesticides, chemical fertilizers, and hybrid seeds in the efforts to make farms as rational and factory-like as possible (Fitzgerald 2003). Where once most American famers had been effectively self-sufficient and raised a diversity of flora and fauna, they were increasingly encouraged through policy, education, and economic changes to reorganize their farms around mechanical logic more suited to high-intensity commodity production, which required inputs manufactured elsewhere. This in turn fueled commercial efforts to commodify farming, creating new dependencies on tractor manufacturers, chemical producers, and, later, seed supply companies. Hybrid technology created in the 1930s permitted the capture, control, and industrialization of seed production, transforming seeds from a renewable asset into a commodified input, a model extended by the legal license to patent living things through genetic "authorship" sixty years later.

Precision agriculture represents to the present what farm management, mechanization, hybridization and artificial inputs represented to the past: a movement to transform objects (and now activities) into discrete commodities, to extend the reach of capital and accumulate entire new geographies of possibility to the market's logic. As violent seizures, enclosures and dispossessions of land were crucial for their later quantification, commodification, and integration into the market; as the hybrid seed was an enclosure of reproduction; as the GMO seed was an enclosure of the cell and DNA itself, so the introduction of so-called precision agriculture is *de facto* the inauguration of a new order of magnitude of enclosure possibilities; the opportunity to delimit and quantify, capitalize and commodify activities, behaviors, choices, approaches, results. The common thread connecting these two moments – the development of mechanically and chemically facilitated field-level management, and digitally facilitated sub-field management – is that of rationalization: at first of physical, and then mental activities.

iii. Algorithmic epistemology – or, how the combine tells the truth

An early step in this process occurred in 1791, when French revolutionary and mathematician Gaspard de Prony embarked on a project to translate the logarithmic tables necessary for accurate shipping into the new decimal system. De Prony's approach was directly inspired by Smith's arguments for the rationalization of labor. Recognizing the essentially algorithmic logic of Smith's rationalized manufactory, de Prony reckoned he could "manufacture logarithms as one manufactures pins" (Campbell-Kelly et al. 2014, 5). Accordingly, he broke the complex mathematical work of the project into a series of simplified tasks, such that the bulk of the labor needed only basic arithmetic that could be performed by out of work manual laborers de Prony hired as human computers.

This was an unusual event. At that time, mathematical calculation was largely regarded as the province of individual human genius (Daston 1994). What de Prony had achieved was a major step in transforming something previously viewed as an exclusive activity of reasoning into rational, even mundane operations. By applying the philosophy of *economic* rationalization to *intellectual* labor, de Prony took an important step towards transforming mathematical reasoning into algorithmic manufacturing (Erickson et al. 2013). De Prony's work on that score in turn influenced Charles Babbage, who recognized that such a discrete, programmatic, rule-based system could be *literally* mechanized; the difference and analytical engines he conceived with Ada Lovelace took the next logical step towards de-skilling the work of calculation, transforming it into just another form of base physical labor performable by menial laborers and the machines. Babbage had essentially designed a factory for numbers, and so even more intimately insinuated algorithmic rationality with economic rationalization (Erickson et al. 2013).

Thanks to Babbage's work, by the mid-19th century the rationalization and mechanization of computing had transformed calculation and arithmetic from the dazzling evidence of noble minds to a type of clerical work so menial it was increasingly left to the undervalued labor of poor and overwhelmingly female workers (Campbell-Kelly et al. 2014). In reorganizing mathematical computation into mechanical, rule-based operations, Babbage's work also laid important conceptual foundations for Alan Turing's theorization of a new kind of machine that, in effect, bridged the gap between mechanized calculation and human computing, integrating the capacity for memory of the latter into the algorithmic production of the former.[23]

From this perspective, development of the modern, electronic computer, the algorithms it embodies, and their subsequent 'invasion' of everyday life were all part of a centuries-long transformation of algorithms from tools of reason to machines of rationality. The rise of algorithmic rationality in economics was substantially assisted, if not outright driven, by the engine of capital and the patriarchal, oiko-nomic epistemology that developed to harness it (on the heteronormativity historically and etymologically embedded in economics as *oikonomia* cum *political œconomy*, i.e. patriarchal authority over a household, see Dubbers, 2006). If modernity entails capital- and state-generated imperatives towards rationalization, and the algorithm can operate across all walks of life as a metaphor for rule-based orders of politics, economics, and epistemology, it is reasonable in turn to describe the globally normative liberal-capitalist order as deeply algorithmic (cf. Totaro and Ninno 2014). And if calculation could be transformed from evidence of genius to the gears of a calculator, and so to a Turing machine, why couldn't other supposedly exclusive human properties or mental activities, in a world now so increasingly rationalized, be subject to the same process?

Many answers to these questions emerged over the second half of the 20th century: game theory, cybernetics, artificial intelligence, information theory as narrated by Gleick (2010), and more recently machine learning, algorithms, and big data. These discourses are the origins of a more recent form of algorithmic normativity, part of the "era of Big Data" (boyd and Crawford 2012, 663) to which precision agriculture belongs. Today "big data" and algorithms go hand in

[23] Thus, as postwar electronic Turing machines lent computing and digital labor a renewed prestige, women were displaced as the chief programming force by a new wave of male programmers, and computing itself was recast in explicitly masculine terms (see Ensmenger 2012).

hand: the utility of large data sets explicitly depends upon the possibility of parsing and processing them algorithmically; particularly for so called "smart" applications where predictive and correlative data analysis is required. If the early modern history of algorithms represented a movement towards a kind of mindlessness *qua* rationality and recursivity, i.e. learning how to mechanize skills and thoughts, the late history of algorithms is that of a data-catalyzed shift back towards mind, but of a different sort: learning machines, artificial intelligences, cognitive science, automata. Data-driven minds harvesting occult, emergent truths from deep oceans of data; algorithmic oracles channeling a newly legible wisdom of crowds.

Chris Anderson (2008) and Cukier and Mayer-Schoenberger's (2013) now-famous provocations about the big data and algorithmic "revolution" are exemplary of this vision of computers as epistemology machines which has grown increasingly dominant in the past two decades. Growing faith in the application of so called "data-driven" models, analytics, and solutions to complex social and cultural issues, something boyd and Crawford have described as the "mythology" of big data (2012, 663), has led to calls for the algorithmic rationalization of once ostensibly exclusively human practices, including government (Medina 2015), policing (Ferguson 2017), taste curation (Hallinan and Striphas 2014), and much more. Once you have a computer, it turns out, everything looks like a datum.

Pushes for more algorithm-driven management of economics, culture, politics, or everyday life involve some by now well-established discursive tropes: computing is objective, humans are fallible, data is the harvestable raw matter of truth (Gitelman 2013). They also often invoke the rhetorical trappings of egalitarianism and democracy: on the one hand, because data and computers are treated as unbiased, and on the other, through appeals to the crowd and its wisdom; the idea that "crowdsourcing" of data is a more egalitarian path to truths and best practices than are ostensible experts.

This discourse is very much at play in precision agriculture. Among the most prominent recent businesses in PA, for instance, Farmer's Business Network (FBN) explicitly presents itself in this idiom. FBN markets itself as an "independent and unbiased farmer-to-farmer" network, that "democratizes farm information by making the power of anonymous aggregated analytics available to all FBN members … [FBN] helps level the playing field for independent farmers" (Farmer's Business Network 2019). The "network" in FBN is that of their farmer members, who pool their agronomic data --varieties planted, yields, machine data, marketing and finance data, etc.-- into FBN's online platform, which its co-founder characterized as "a technology-aided version of the small talk farmers would make at a coffee shop or supply store" (Konrad 2017). In short, FBN seeks to "disrupt"—that is, supplant—the informal, embodied, local social institutions of US farming where farmers meet and talk shop, with a crowd-sourced data platform that offers "the combined intelligence of millions of acres" and "radical price transparency" (Farmers Business Network 2019).

This move to equate data with a kind of straightforward, democratic functionality is a salient facet of emergent algorithmic rhetoric, embodied in the marketing claims throughout the agricultural supply chain and in established elites of digital commerce like Amazon and Google alike. Yet I agree with Striphas (2016) when he argues that what is at stake in this phenomenon is the "privatization of process" (406). Contrary to the revolutionary, democratic language that shrouds them, what elite companies like FBN, Deere, and Cargill, let alone Amazon, are in fact engaged in is an effort to commodify and privatize public spaces, social activities, and cultural phenomena like coffee shop talk by apprehending them within the quantifiable logics of digital capitalism at the core of algorithmic rhetoric, all the while claiming the opposite. Furthermore, if as a farmer both the software running your seeder and the very seeds you plant are subject to IP protections, you no longer even meaningfully "own" the equipment you buy. Instead, you essentially license critical parts, which you thus cannot repair yourself (Sykuta 2016). Yet in order to actually receive the advantages and value promised by precision equipment, you must simultaneously share highly specific data about your farm operations—data your labor generated—for free. In such a situation it is difficult to take the rhetoric of crowd wisdom and algorithmic democracy seriously.

In precision agriculture, acting, thinking and doing are themselves subject to commodification via datafication. These phenomena can be translated from the indiscrete realities into quantifiable, tradable functions. They become inputs to be bought, and increasingly, to be licensed—rented rather than owned. This is not so much a revolution of ideals or ontic kind, but an expansion of market development and industrialization, ideologies of growth and structural transformation that demand life and food be industrialized in order to be incorporated. Digitization provides the opportunity to capture, access, manage and exchange what was inaccessible before; not unlike the ways climate modeling software now permits futures trading on environmental catastrophes (Johnson 2012).

How does viewing precision agriculture this way change or challenge its popular, revolutionary ideation? Consider the combine. These machines, which developed in form and function beginning in the 1830s, were so named for integrating several different harvesting activities (reaping, threshing, and winnowing) into a single machine. Transforming those ancient and variable practices into a series of mechanical steps is exactly akin to the algorithmic process of rationalizing and mechanizing textile production. If the farm could not at first be brought to the factory, the factory would be brought to it: the combine is itself a factory producing commodities, a kind of roving, metal algorithm. If older combines were simply that – mobile factories – today precision-equipped combines simply extend the logic and domain of this process to a number of additional input and output processes, including the quantification of traits (starch, protein, moisture contents of seeds etc.) and telemetric data (fuel efficiency, route efficiency, time driven, etc.). Modern combines are factories producing both data and crops in increasingly elaborate detail. This detail, and those data, are useful first and foremost in establishing the relationalities essential to the production of commodities as such, and so to the production of capital.

This is how a combine "tell[s] the truth." It tells the truth in the sense that it reliably generates quanta relevant to the functional relations of commodities and capital that organize the entire system industrial, "conventional" agriculture. That is, it would be absurd to say that in expressing the starch or moisture content of a kernel of maize the combine is telling the truth of that maize. The combine-as-computer tells the truth insofar as it supposedly does not engage in deliberative, contextual, positioned judgments like a human being. Rather, it "tells the truth" insofar as it first and foremost accurately and consistently generates information relevant to the conversion of corn into a commodity-logic of function, into an object of value measured by the metric of labor relations called money, into a thing legible to capital.

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. This logic has taken on a newly mystical dimension with the introduction of machine learning, big data, and algorithmic epistemology, which have in turn led to a contemporary use of *algorithm* as a cipher for the occult-yet-objective, truth-generating powers of what are more accurately understood as John Deere, Nestle, or DuPont's efforts to preserve their industry by monetizing behavior.

IV. Conclusion

This chapter has outlined an epistemological relationship between industrialization and information by introducing the concept of an "informatic ideal," in order to advance a critique of precision agriculture discourse. This discourse, which frames precision agriculture as revolutionary, belies the more mundane reality of digital farming as heir to a now centuries-old historical process. Precision agriculture is better understood as an intensification and evolution of dominant, normative modes of relation structured by capitalist organization of production and liberal political-economic philosophy. This is not to suggest that the move to sub-field scales of management, the reorganization of the industry and practice of conventional farming along more overtly informatic lines, or the large-scale spread of information technologies into previously unknown regions or environments do not represent real changes with their own ramifications. It is rather to contend that invocations of precision agriculture and its dazzling algorithmic patina as revolutionary have the rhetorical effect of normalizing the intensive, destructive industrial production of agricultural commodities that is in large part responsible for the very social and environmental problems it is proposed to solve in the first place.

In the next and final chapter of this study, I will highlight what I see as some of the most salient emerging issues produced by the digitization of farming, and present what I see as the fundamental tracks along which such issues appear poised to unfold. I will argue that if information is to be the new substrate of farming, then it seems we are faced with a choice. On one hand, to use informatic control to preserve an imperious, masculine order of factory farming with a new intensity of control that the mergers that opened this essay represent, where behemoth corporations fight over growing shares in worldwide control of land, labor, and food and governments exert digitally-facilitated social control in the name of sustainability and ecosystemic sovereignty. I will frame and develop this perspective in as a dream of *code as law as police des grains*. On the other, following from the work of scholars like Chantal Mouffe and Jacques Rancière, I will advance an alternative understanding of control, rooted in a fundamentally different approach to the politics of agriculture. to take the fineness, the kind of granularity of control and adaptability digital agricultural technologies might offer as a chance to do something genuinely revolutionary: to try and build new relationships to food, land, other species, and one another.

CHAPTER 4: DATA FARMS AND THE GOVERNMENT OF NATURE

I. Introduction

The previous chapter argued that precision agriculture does not, as its proponents claim, represent a revolutionary change in any meaningful sense of the term. Instead, I maintain that in the most important respects, precision agriculture – as a socio-technical system, a discourse, a collection of technologies and techniques corralled by a signifier – is the name for a progressive, evolutionary step in a much longer history of imperatives to increase efficiency, productivity, profitability, and control in farming that characterize the dominant geopolitical and economic orders of the age of the market society (i.e., liberal capitalism). This step is from the dominance of an industrial ideal in agriculture, to its augmentation and transformation in the shape of an emergent informatic ideal.

At the same time, I introduced a caveat: the intensification of a system does not suggest a lack of change or meaningful transformations within that system. Politicizing, historicizing, and criticizing 'disruption' rhetoric does not suggest that there are not real developments with tangible effects unfolding as agriculture – particularly large-scale, conventional agriculture – is increasingly organized around and performed through digital methods and means.

This chapter explores some of these changes. Drawing on fieldwork performed in the US and Canada, I explore a key finding of this research – the growing prominence of data over and above the 'hardware,' so to speak, of precision agriculture, and some significant uses to which agricultural data is and will be put – a finding that fits into the properties and findings of the previous chapters, while also provoking a consideration of the choices and possibilities of precision agriculture moving forward. This discussion will focus on the importance of *transparency* and *traceability* in agriculture as a product of the produce of data, of data farming, the significance of which emerged over the course of my research.

Based on these findings, I argue that precision agriculture's extant design philosophy – its dominant socio-technical imaginary, so to speak – is most accurately understood the light of much broader approaches to identify, integrate, and control environments, things, life itself: a kind of dream of the "government of nature." I contend that the motivating and organizing knowledge and power structures which characterize precision agriculture as a technical system, as a discourse, and as an industry, represent a vision of *code as law as police des grains* integral to achieving that government. Following the discussion of data, transparency, and traceability, I will offer a brief genealogy of precision agriculture as a form of *police*, aimed at the government of nature in the name of sustainability – which is to say, sustain-ance of the dominant, normative, socio-political, economic, and ecological order of liberal capitalism.

This characterization in turn raises a question I want to pose as a means to close out this study in its concluding chapter. Specifically, it would appear that this trajectory, rooted in the effort to maintain the existing social, political, and economic relations that characterize the existing agri-food system, is likely to at best promise a kind of increasingly tightening regulation of things and actions in the name of sustainability (of the present), the worst iteration of which would ultimately take the form something like a kind of eco-fascism. Such a future is hardly inevitable, or even necessarily likely, and there is nothing about the development and use of digital technology in agriculture that guarantees or dooms it to an allegiance to an environmental police state. Consequently, why not take more seriously the impossibility of holding on more tightly, more perfectly? Why not make a real revolutionary choice – a democratic, equality-extending one that takes the existence and mattering of non-market forces and non-human species as seriously as they need to be? I will outline a preliminary answer to these questions by drawing on work by Jacques Rancière and Chantal Mouffe, among others, suggesting what a genuinely "revolutionary" use of digital technology might be rooted in, aimed at, and contribute to in terms of the political-ecological future of the world we share.

First, however, in the following section I discuss a few of the more significant findings that emerged from my fieldwork and research over 2017-2029. Specifically, I highlight the waxing discursive and technological prominence of data in precision agriculture, seemingly over and above machinery in digital farming practices and imaginaries; and, relatedly, the discursive and technological significance of "traceability" and "transparency" to the future of US (and beyond) agri-food systems.

II. "We are able to see" (on the Data Farm)

This project began as a study of drone use in agriculture. Already interested in the domestication of military perspectives, ideals, technologies, and techniques, I had begun to study the development of so-called "unmanned" aircraft for warfare, the discourses that had developed around their uses over decade into the "War on Terror," and more recent evolutions in drone uses and imaginaries during my first year as PhD student. Some of these latter developments included efforts to adapt living things to military uses, such as the DARPA-funded research projects investigating the transformation of insects or birds into drones by attempting to digitally hijack their nervous systems, as well as the adaptation of explicitly martial technologies to ostensibly non-military domains like policing. I was interested in the question of whether, and to what degree, a technology conveys, constrains, or carries an intrinsic means of relating to the world; in other words, whether using military technologies in other areas of social, cultural, or political life involves effectively militarizing them, epistemologically or ontologically speaking.

At this point, between 2013 and 2015, such questions as applied to drones were largely speculative. Drones did not become legal for domestic use in the United States outside of specifically licensed exceptions – like for certain police departments, or on a case-by-case basis for private entities – until 2016. But during that time I came across a statistic that I found arresting, and ultimately led me to this project. According to a 2013 report by the major industry organization for autonomous machines, the Association for Unmanned Vehicle Systems International (AUVSI), the chief domestic use of drones – up to 80% – was predicted to be in the agricultural sector, not policing (Jenkins and Basigh 2013). I was intrigued, as my most fundamental academic interests all touched, and touch, upon the processes and effects of constructions of humanness, especially their histories and political ramifications, and industrial agriculture is arguably the most intensive explicit site of inter-species relations in the contemporary world. Studying drones in agriculture would combine my interests in the ontology of information, the military history of digital technology and contemporary politics of martial information and media technologies, and the construction of thresholds of humanness, particularly in agriculture.

This interest led me to the field of precision agriculture, the field in which the use of agricultural drones is incorporated and was unfolding. Through a series of interviews with equipment dealers, businesspeople, and Extension Service academics, along with a review of existing precision agriculture literature, I quickly recognized that drones were, at best, a peripheral and very young aspect of precision agriculture, by no means essential or integral to the practice. While growing in market presence and technological capability, and a significant focus of hype, it was clear that drones were simply one element in a broader and older pursuit of command and control on the farm.

At the same time I also began to learn that for many stakeholders engaged with the development or uses of precision agriculture, hardware itself – devices like drones – appeared to be of increasingly secondary or tertiary interest. None of my informants, up to and including a representative of a major agricultural drone company that was in negotiation with John Deere when I spoke with them, seemed to think the drones themselves were particularly significant or uniquely interesting, or that their use represented anything other than an opportunity to do what satellites and planes already did, but better. As the drone representative put it, “drones are a tool in the toolbox, but they’re never gonna make you money. What’s gonna make you money is the data that comes off of here.” That is, what mattered more to them, both in terms of possibilities and problems, is what the drones – and the tractors, combines, satellites, sensors, weather apps, digitized silos, computer programs, and media infrastructures – made possible: the production and harvest of data, and so in turn the production of opportunities for finer control. The drone rep was explicit on this point: “The airframe really doesn’t matter. It’s the data that comes off that airframe that matters.”

Farm data is seen as significant for more reasons than can be meaningfully covered here. But a few stand out. One is way that data is perceived as offering insights into the administration and governance of the farm from the perspective of its owner-operators. As we’ve seen in Chapter 2, precision agriculture technology provides opportunities to generate and gather large amounts of data in real or near-real time from as diverse an array of sources as one has sensors, including biometrics on plant and animal life, weather forecasts, input expenditures, equipment telemetrics, and infrastructural status.

One large-scale dairy farmer in the North Country of New York I spoke with illustrated the significance of this last element – infrastructural data – to his operations by pointing to million-dollar investment in new bunker silos equipped with moisture, weight, and other sensors. The value of this update wasn't so much the new physical facility itself, as the sensor data's affordances for eliminating "shrinkage" of silage – dairy cow fodder – during storage. Shrinkage is loss of harvested and stored dairy cow feed by various factors, including fermentation during storage. The farmer explained that even "just measuring quantity is huge; what do we have in storage, what do we have in feed that's harvested. [It] allows you to know the inventory, what's the value of that inventory, what's the shrink of that inventory." Having this data at hand helped them reduce "shrink by over 50% in the last few years" from 21% to 10%, no small feat considering that prior to this investment they had thrown away "$325,000 worth of feed in 2013." As he put it, "the one thing about precision ag is we have data - we knew what we were losing, we knew what we were harvesting and what we were feeding, and we knew what we were throwing away."

John Nowatzki, Agricultural Machine Systems Specialist at North Dakota State University, saw benefits in the aggregation of data over time and across types when I spoke with him, because "farmers are just getting to the point now where they're making use of … historical [use] data on each field." One could combine, for instance, the fact that "this [field] used to be a pasture, the previous year's soil test, [the] current year's soil test and moisture, and then all those previous years of input, whether it's herbicide or insecticide or fungicide, fertilizer, and yield data from previous years." Putting all of that data together, he said, was the "next step" in digital agriculture. The real promise he saw was in putting such data to use "in real time," where

> we will take all the data that's available, and feed it into computers - a machine learning system - and then in addition to that, collect data as the machines are operating down the field, in the field, and feed that in real time … and then be able to process and feed it back out to those machines. So for example, we would

> know where an area, maybe the imagery would say there's a shortage of nitrogen in this area, but the other data would say no the pH is wrong in that area, it's going to be waste of fertilizer to put on there …That's our next step, and I think that's the next step in precision ag, which is digital data management in and use of that [data] in real time.

Relatedly, data-based amplification of the ability to administer and manage more and larger farm operations with simultaneously finer granularity was repeatedly singled out as a significant advantage by famers, researchers, and officials I interviewed. This included one particularly large farm in central Ohio, which had adopted a leading digital agriculture platform, the appropriately named "Granular." One of the partner-owners of this farm explained how the mediation and datafication of labor and machinery in particular made labor management and machinery analysis possible in far more powerful and detailed ways than before. She offered the example of digitally generated insights that, on one hand, translate to financial savings on equipment. Trade-in value for farm equipment, for example, is measured partly in terms of hours operated, just like value for cars is measured in mileage. Digitally-equipped machinery that feed telemetric data back to Granular about its various systems and usage can inform company policies around machinery usage, where the farm owners can see whether a tractor is left running while it waits in a field for repairs or seed to arrive, burning fuel and hours that decrease its trade in value and waste money. It can also be used to compare pieces of equipment: when the farm bought a new high-speed bean planter, for instance, the farm used telemetric data to measure its performance against the older model, determining whether the investment was worth the gains, and helping to identify mechanical or "employee issues" if not.

Such employee issues were not only peripheral to questions about machine operation, but themselves constituted an explicit focus of attention through data collection and analysis for every farmer I spoke with who used digital technology in operations management. The picture that emerged across these interviews resembled an Amazon warehouse more than any traditional image of the family farm.[24] The Ohio farmer I spoke with offered an especially detailed and instructive example on this point, worth quoting at length. The workers on their farm are all given phones, and each phone has a Granular app that links their activities to those of a given piece of equipment they run, whether it's a combine, a tractor-trailer, or a grain cart. Consequently,

> **A**: Through Granular we're able to check based on the time that they're-- so everybody's app is tied back to them. When they stop and start a work order we're able to see the amount of time that they're spending in the field, so as soon as they physically start the task they're starting on their phone, and you can see that-- and through that they also pick the piece of equipment that they're in, so there's different reports that you can run if you want to run it by employee, if you want to run it by a piece of equipment.
>
> **Q**: So you've got an employee tethered to an ID in a piece of equipment, and you know specifically which machine that is, so you're [gathering data] on several levels?
>
> **A**: Yes, yes, yeah … I can use myself and my cousin for [an] example. He's on the operations side, operations manager. He knows that employee A is always in tractor A and that this tractor has had issues, that it's broken down multiple times, hydraulic leak, whatever it is, all these different things. Well, here I am on the inside, and when I'm pushing out our cashflows and different things from a cash standpoint and … let's say they say "Oh, we need to trade this piece of equipment." Now I have information backing that. It's not just him saying-- not that I wouldn't trust him anyway, but at the same time it's not just him saying "Oh, we need a new tractor." It's "We need a new tractor. Here's all the things that have happened throughout the season," and then I can verify that it did slow us down. It planted 500 less acres, and [R], who's one of our most experienced employees, was in it the entire time. The past four years has shown us that he's our most efficient person in a planter. Well, this year he had less acres … as we continue to grow and there's more people that are making more decisions … **I always want to trust my employees, but at the same time it's nice to have things to verify for them, [and] that these actions that they're saying are taking place are physically taking place** [emphasis mine].

Farms that increasingly harvest data along with crops or milk – literal data farms – reap, thresh, and winnow information about more than just plant growth rates, bovine body temperature, or the weather, and precision agriculture is precise in its governance of more than one kind of field. Data is if nothing else a quintessentially *administrative* technology, and technologies – e.g. the mediating conditions of possibility for a given cultural technique – are not neutral, to state the obvious. They do not determine, but neither are they simply adsorbed wholesale into existing structures that otherwise remain unchanged.

[24] One keynote speaker at an industry conference at Purdue in 2018 made this point explicitly, suggesting that several different agricultural companies were in a race to become the "Amazon of agriculture."

Data represent a technological medium that acts as much like seeds on the wind as colonizers on ships: both seeds and settlers do not merely take root in new places, they remake those places in their own image, as both Alfred Crosby (2003) and James Scott (1998) famously argued, and as the standardizing standards intrinsic to the orthographic concept of precision itself (re: Chapter 1) let slip. The same is no less true of data, especially in its contemporary, digital form (Bowker and Starr 2000; Daston and Galison 2007; Gitelman 2013). Or to paraphrase – and reverse – Alan Turing's (in)famous characterization, computers are the medium that make all other media become them (1950). Data is the thing that makes things like data, it tends to render the ontic in terms of its own ontologic. And, in the context of the overwhelmingly privately-owned, for-profit, conventionally industrial American farm, where the divisions between the owners of the means of production, the objects of those means, and the workers of those objects are organized 'economically' (or better, "agronōmically,"), administration technologies can be expected to express the administrative imperatives of that context they co-produce: namely, of capitalist relations of production and the figure of the patriarchal sovereign of the household embedded in the administrative hierarchies endemic to that form.[25]

Consequently it is unsurprising to see human labor being treated, from a managerial perspective, as a site from which confessions must be coaxed regardless of whatever a worker actually says on their own behalf, the same as cows in a CAFO or alfalfa on a hillside. Here again the image of the truth-telling combine rolls back into view, saying its sooth about dirt and soy in a digital tongue.

In my interviews with precision agriculture adopters – which, again, in keeping with the trend observed by the USDA's surveys of precision agriculture adoption (e.g. Schimmelpfennig

[25] More on this in the following section.

2016) were overwhelmingly large, profitable private farms – I was repeatedly told that these farmer’s businesses could not continue operating or growing in their current forms without data, computers, and digital communications technology. Data, and the computational and telecommunications infrastructures for generating, mediating, and processing it were seen by such interlocutors as an absolute condition of possibility for the future of their kind of farming: “I find comfort,” the Ohio farmer told me, “that we can still farm in the way that we were founded to farm when my grandfather first started, because we're using the technologies that we're using, because **we can farm five counties away, and I can sit behind my desk and pretty much see everything that they're doing”** [emphasis mine]. One consequence of precision agriculture, that is, appears to be its potential for hastening long-established trends in US agriculture, helping large farms to grow larger, and consolidation to further accelerate.

Part of this utility is related to the part that precision agriculture platforms like Granular play in putting multiple forms of data gathered from disparate sources like inventory control, delivery management, yield results, marketing information, human resources administration, and vehicle performance on a common tableau and in communication, as argued in Chapter 2. “Having all the data in one place,” as the Ohio farmer put it, reduces the need for workers and offers ‘scaleability,’ extending the capacity to govern more operations over more land. Furthermore, there are a variety of initiatives, such as those spearheaded by the Ag Data Coalition and Open Ag Data Alliance, to create common standards that bridge the multiple existing forms of proprietary agricultural data, ostensibly for increasing farmer trust in agricultural data’s usefulness and privacy.

Data and data management technologies however, while always the technological *a priori* upon which precision agriculture was constructed (e.g. GIS), were not always so celebrated within the field. As with any technology, data generation and computer processing create both affordances and limitations, possibilities and problems. The very complexity of digital agricultural technologies framed as a boon above is also the source of significant difficulties for farmers both past and present. Complex farm data technologies in many cases require specialized training to use, training that costs in time, money, energy, and other ways. Sensors and machinery require constant calibration, for example, to tell useful [ground] truths. Learning not only how to calibrate correctly, but across potentially several different machines, as well as to integrate those practices into the habitus of one's farm can be a barrier both to the adoption of and to the use value of precision agriculture equipment, particularly for some smaller-scale and older farmers. The New York dairy farmer quoted above highlighted this issue of mindset repeatedly, as a way to explain why his farm not only integrated precision agriculture technology but did so successfully in contrast with the low adoption rates across New York state in particular and the rest of the country in general. Not only does not having the right attitude shape whether or what someone adopts in terms of precision agriculture, he argued, but it can create problems further down the road:

> Now it does put a whole new level of complexity in the running farm, and if your mind's not wrapped around it, you're not going to be successful. John Deere's become a master of selling a lot of [precision agriculture] equipment that farmers never even really ever learned how to use. They sell them the yield monitor, but the farmer hasn't calibrated it in four years, doesn't even know how to calibrate it – well, he's not getting any value out of that yield monitor. He may feel good as he goes across the field if it's telling him he's getting 300 bushels to the acre, but he may not be getting 300 because he hasn't calibrated it in three years. So I think that's a disservice to the industry when they convince guys to buy stuff and then don't follow up.

A Central New York agricultural equipment dealer selling precision agriculture equipment encountered its misuse so often he even had a term for the information generated by mis- or un-calibrated machinery, "dirty data," one he used in conversations and presentations with local farmers. Dr. Bruce Erickson, an agronomist working at Purdue University who conducts influential research on precision agriculture adoption rates in US farming highlighted a problem at the other end of the data farming process. Even if you get 'truthful' data from your correctly calibrated machine, he explained, "the data's no good unless you have people that understand the data and what it means:"

> The key thing is, what do you do with the data? … so you've got a UAV, and you have [multi-spectral imagery data]. So what does that tell you about this part of the field, first of all? And then, once you maybe can see that there are differences, then what do you do? Do you put on more fertilizer or less fertilizer? Do you do a different hybrid? And that is very unclear, what should be done … Now, one thing that you could identify is that yes, you can see that this part of the field is very different than this part of the field, and that, then, can open up the investigation, to try to figure out, why does this corn look so weird over here, and it looks normal here? Something must have happened here. **But [the data] doesn't tell you what happened** … It might-- the pattern might be obvious, or it might reveal itself, but in most cases, it doesn't. (Erickson, interview, 2018; italics mine)

This sentiment was shared by many of the agricultural researchers I interviewed. "It's easy to collect tons of data, the question is how do you make the data useful," as a Cornell researcher attempting to use drones to assist in plant breeding put it.

An interview I conducted with another Cornell graduate student highlighted similar concerns from a different angle. This PhD student, at that time conducting research at the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, originally made famous by Norman Borlaug's "Green Revolution" research on wheat varietals in the 1940s, expressed her dissatisfaction and frustrations to me with precision agriculture as both a discourse and a technical system along similar lines. "The whole thing that bothers me about the data thing is that year to year variation is so huge" she explained. She felt the research and development coming out of both private and public institutions varied so much and changed so quickly it was not particularly useful to anyone besides the researchers publishing it. Consequently, for her, it represented hype more than reality, and was in some respects doing harm by creating a false sense of possibility and faith in technology.

She laid responsibility for what she saw as the glossing of failures to make agricultural data useful – and by useful she emphasized she meant useful to people and the environment in general, not only farmers – at the feet of the "culture of science" of the present, in which "publication is king." "In order to make technologies useful you have to have the base level infrastructure there, and that's not attractive to funding" she said, arguing that among scientists "our currency is publication … so where's the incentive to do something with the technology after? … at least for academics, I feel like there's no incentive to do the extra legwork to get the new innovation into a form that's really useful." As she saw it, research tends to stop at the point of publish-ability, without the follow-through necessary to make findings or knowledge meaningfully useful. This researcher explained that she originally chose to pursue work in this field, and her advanced degree, specifically in order to try and help people, to help the environment. Despite performing cutting edge precision agriculture research as a member of two of the most elite agricultural research institutions on the planet, she shared that "I don't feel a part of that [helping people in the future], I don't feel like I'm helping, and I feel like that has so much to do with the culture of science." In a complex socio-technical system like precision agriculture, in other words, it is unsurprising to find that limits and complexities manifest in both its technical and social dimensions, including in the cultures of scientific and industrial research that help to produce and maintain it.

Staying with the issue of conceptual and technical complexity, but shifting our attention from research to consumer phenomena, I also found many of my informants highlighting how important education in information technology, programming, and similar fields will be for future generations of farmers. Such education requirements present a real barrier to farmers without the means, time, or capacity to adapt to such systems – or to hire those that do. In fact, as noted in previous chapters, many in the agricultural industry writ large see a future in which specialized data analysts will become essential members of staff, playing a hand in major operational decisions and possibly even required in order to operate certain kinds of increasingly automated or computerized farm machinery correctly, whether planting seeds, surveilling livestock, or running a combine harvester.

According to many of my informants across farming, industry, and research, it is relatively common to see large amounts of generated data simply go unused. One agricultural scientist estimated that of all the data that milking robots collect, “producers use maybe 15%.” When I asked Nowatzki about similar under-utilization of data in field cropping, he laughed:

> I don’t know! I think because the data, in order to make use of it you need a GIS computer program, and most farmers don’t have training in GIS. Secondly, it takes time at this point. Basically, to me, in order for farmers to adapt technology, it has to be first of all affordable, and it hast to be reliable, but it has to be as easy as turning the radio on in the cab of their tractor. Almost that easy. **And that’s why I think farmers are not using their data – it’s just too much work. It’s one thing to do it for one field, but if you have a hundred fields it takes a lot of time. So that’s why I see the next step is going to be; to move forward now we’ve got to have an automatic computer system. That’s how I see it.** (Nowatzki 2018)

The possibilities and drawbacks of data-driven automation like those outlined by Nowatzki are a regular facet of discussions about precision agriculture. I encountered a wide range of takes on this issue, from futurist imaginaries of completely automated farms, to the picture of a farmer followed by a fleet of drone tractors from a lead control tractor, to outright rejection of the notion that ‘driverless’ automation of any kind is on the horizon. Yet much like Moradi and Levy (2020) argue regarding automation in general, my research thus far has suggested the processes of agricultural automation[26] are more likely to involve increasing the intensity and breadth of surveillance over human workers, as opposed to the simple replacement of people with robots and computers.

[26] By automation I mean by both mechanical and computational means; the term “Artificial Intelligence” is a flawed and misleading one, more a kind of marketing term than meaningfully accurate signifier. Similarly, “machine learning” and “neural network” indicate more specific technologies or processes than computational automation in general, and themselves present similar issues to “AI” regarding the connotations and denotations of words like “thinking” or “intelligence.”

A farmer with a very large operation in Kansas raised this issue explicitly when I asked him about the notion of drone tractors. On such large farms, using expensive, complicated equipment like combines or seeders that have been only made more complex by digitization, potential issues and problems multiply as well. On a large field crop farm, for instance, much of the actual work of harvesting, planting, etc. is performed by hired wage laborers, who will run the seeders or drive the harvesters. If a tractor breaks down in the middle of a seeding run, one possibility is that the hired operator can fix it themselves; if they cannot, the farmer will have to service the tractor, which will have to wait, sometimes in very remote places, for assistance to arrive. There are significant time pressures in this scenario, as the windows for operations like planting and harvesting can be exceedingly narrow in terms of a successful or unsuccessful crop. Adding several driverless 'drone' tractors to this scenario multiplies the potential to seriously exacerbate any such problems as they arise. So, this farmer pointed out, even in the scenario described above, where in place of full automation one has a semi-automated fleet of three seeding machines led by a single driver, if one of those seeders has to stop in the middle of planting "because row number two's plugged, [are] you going to stop two other planters to go fix one?" Fully 'humanless' automation, they said, is even less possible due to issues of this kind: "if somebody thinks they're going to live in New York and have a tractor in a field and it's going to go back and forth [over that field] without stopping they're crazy …you're not going to replace a person … that either sits in the tractor or sits at home. Someone's got to watch that tractor, right?" He went on to outline a scenario in which a farmer, using a whole array of cutting-edge precision agriculture technologies, attempts to automate their field operations:

> So [for example], 'Let's take a drone out there, fly over a quarter, 160 acres, upload it into the tractor so it knows where all the crevices are, all the ditches, it knows how to turn around all the way everything, [so] you can't hit anything [with the tractor] right?' So you drone it, pull up a chair up, [the computer] gives you full satellite imagery, you see everything you need, it reads elevation changes, I mean absolutely everything, best case, best stuff you got, put it in the tractor: [then a] row unit stops because the planter got

plugged. Who's going to fix it? I mean, not a guy in New York. You still can't-- the point is you're not going to get rid of an operator. I mean are you just going to let the planter sit there for five hours or ten hours?

While this is a hypothetical future scenario, such problems are already very much a reality for farmers who have adopted precision agriculture equipment into their operations: “I'll tell you, technology in this farm equipment is not a good thing when it comes to reliability and serviceability,” as a New York farmer put it to me.

The issues presented by intellectual property ownership and service contracts with farm equipment is one area of precision farming that has received high profile general press coverage over the past few years. Many precision agriculture technologies cannot legally be serviced by unauthorized personnel due to the service contracts and IP licensing agreements that govern their sales and use. “That creates another whole problem,” the New York farmer pointed out, “because you talk about ‘we [the equipment supplier] can't service you,’ how do you get a hold of the software” to diagnose or repair a problem occurring in a system under IP protections?

Do you pirate some software – which, that's what most of us do – and get some cables and pirate some software and buy a computer that you can [use to] read [error] codes? Because otherwise you're sitting at the end of the field and nothing will happen, you're not planting corn, you're not harvesting because the thing says you have a code and you can't read the code unless you can plug the computer into it. So you're either sitting there waiting for the [service agent], and it could be something as simple as a sensor that you could simply then go into the computer and delete it so that the machine doesn't even think it has that [issue] anymore, but you got to be able to do that.

The power of (legal) code over (computer) code and the problems their interaction can present raises a directly related issue. If data, not machinery, are the growing focus of precision agriculture for many farmers and researchers, the same can be said in many respects of government offices and agricultural corporations – even equipment manufacturers like AGCO and John Deere. Like Terms of Service contracts for iPhones or the use of social media platforms, precision agriculture technologies that generate data license that data's use and control to both the farmer and the company or service provider. They are also potentially subject to use by government agencies, from the USDA to the EPA. In other words, while a farmer can use the data generated by a Sentera drone to, for instance, plan soil treatments or pesticide applications, that data is also gathered and used by Sentera and analyzed across an array of metrics and indices. Chapter 2 raised the question of the specificity of farm data, an object to which legal professionals in the agricultural domain have started to pay close attention, developing sample agricultural data contracts for farmers to use with agricultural technology companies and advancing their own interpretations of agricultural data's complex legal standing and definitional properties. The question of data uses is furthermore not necessarily one of ownership *per se*, because like other kinds of data the uses of agricultural data are not governed by property rights, but contractual and licensing agreements. Such agreements often stipulate that a farmer 'owns' their data, but such clauses that is effectively meaningless in terms of privacy or control, because those same contracts will also license usage parameters – and therefore, control – of that data by the contracting company as well as the farmer.

This is a concern from one perspective, because according to legal scholar of agricultural data Leanne Wiseman, 78% of the farmers she surveyed had "no idea what their contracts contained" (2018). This is, to be sure, much the same situation in most walks of contemporary life, as is the way such contracts are signed – essentially, as a requirement to use a given agricultural service or technology. As Wiseman put it during an address at the International Conference of Precision Agriculture in 2018, "anything you turn on these days, whether it's a sensor, a drone, basically you're clicking 'I agree,'" which is a pointed problem for famers, who unlike, say, an Instagram user, does not have the same privilege of simply not using the service: "You can't not turn on your $300,000 tractor because you don't like clause 58c."

Most of the PA-adopting farmers I spoke with did not have an issue *per se* with allowing agricultural companies access to their data, seeing it as a necessary cost of doing business and potentially as a source of future efficiencies and savings through analytics. Given that my interviews for this project were chiefly with people who either worked on or with precision agriculture equipment, however, I am unable to speak to attitudes among farmers who have chosen to adopt little to no precision agriculture equipment. The fact that in the 3 year period during which I conducted field research almost every talk, panel, conference, or presentation I attended involved some element concerning farmer "trust" in digital technology suggests that pushback or concerns are, at a minimum, not uncommon. Yet even among enthusiastic adopters, like a large-scale dairy farmer I spoke with, objections, questions, or hesitations still existed. He and his colleagues felt there was an unfair relationship between farmers and industry on this point, and wanted to know "why doesn't data have value? Why should we be giving this data away [for free] to these big companies? … we're spending millions of dollars to plant a crop and they're seeing everything that we're doing and learning from it real time."

If opinions on agricultural data use by commercial interests ranged from uncontroversial to mixed among those I spoke with, governmental use of data was often a different story. During a ride-along with a farmer harvesting a field in Western New York, I raised the issue of data usage by both commercial and state edifices. While this farmer had mulled over his feelings about corporate data collection and decided it was largely beneficial, he was surprised when I asked his opinion about the potential for government collection of data for economic or environmental regulatory purposes, something he explained he had not quite considered, and that appeared to make him warier about what Daniel Solove calls "secondary" data uses by commercial interests:

> I guess I never thought of it that way. I never thought of the state using the data for something like that. I always felt as though I could physically see where Deere could use it … And I could see the benefit to us. With the state, I guess, I'm a little bit more reserved because I'm not-- I guess it's not the ag company looking at it on how to make something better for us. But I hadn't even thought of it on that level. What would be more concerning for me is if Deere started being the one that is relaying the info. <laughs> That would probably be a bigger concern for me. And it could be. That could be happening and it could happen down the road.

Based on even my limited and largely preliminary findings, it is obvious there is an enormous amount of further critical research to be done in this area. It is clear that agricultural data is generated in abundance and growing more abundant with every year, especially following increases in computational power and the reach and power of environmental media technologies over the past decade. The growth of data farms has produced a series of new challenges and problems tied to the specificities of digital technologies, including but not limited to those discussed here: 1. Much of the data generated can be flawed (or, "dirty") without following strict procedures to ensure its accuracy ("religiously calibrating" as an Indiana farmer put it), 2. even accurate and abundant data may not easily translate into clear insights or usefulness, 3. Data increases opportunities for surveillance that affect the organization of power within agricultural concerns, from relations between labor and owners to the increased capacity for large farms to manage more land, increasing opportunities for expansion and further farm consolidation, 4. with data come IP protections that create their own sub-family of issues, and 5. the uses of farm data by external entities, whether commercial or governmental in nature, themselves raise a series of questions, problems, and possibilities, issues that warrant urgent and dedicated critical attention.

Nevertheless, there was, and is, significant enthusiasm for digitization of agriculture among the larger farmers, academic researchers, technologists, and government officials I spoke with and observed, to say nothing of the agri-food industry itself. This enthusiasm has much to do with the perception of greater control and profitability thoughtful adoption and uses of precision agriculture equipment many in the agricultural industry share. "We can't control the weather," one farmer explained, but with precision agriculture "we can control a lot of other things: how do we put our resources where we can use them, get the most return, how can we limit the amount of resources and maximize return, that's really what [it's] all about." More fundamentally, however, the common thread across the proponents of precision agriculture I have observed throughout my research was probably most succinctly expressed to me by the Ohio farmer I interviewed. With precision agriculture, she said, "we're able to see." And among those for whom agricultural data gave sight, none seemed more interested than the processers, purchasers, and peddlers, and police of agricultural produce: food companies, grocery chains, financial institutions, and governments, among others, all of whom betrayed a keen interest in further developing what are commonly known as "traceability" and "transparency" across the agri-food system.

III. "Be willing to disclose everything" – Traceability and Transparency

One of the more interesting phenomena I encountered during my fieldwork had to do with what I can only describe as a pair of fixations shared by farmers, marketers, extension agents, technologists, corporate executives, university researchers alike: first, with fake meat, and second, with verbally asserting one's allegiance to capitalism. I say fixation, because both topics came up with a genuinely surprising regularity during my research from 2017 to 2019. I found even more interesting the fact that they were connected.

First, the "meat." A significant number of my interlocutors, and an even higher percentage of the speakers and presenters I encountered during my research, were remarkably interested in the figure, concept, and future of fake meats. As a person who hasn't consumed animal products for nearly 20 years I was genuinely surprised, and definitely amused, by the hubbub over the modest, recent gains faux meats and other animal products have made in market share and shelf space in American grocery stores. People were not only interested in them, however: they were annoyed.

I was confused. What was the big deal? Why did everyone seem to care so much, to be so bothered by beyond burgers and impossible meats, so fixated and contemptuous, especially when I had already been eating great meat substitutes for at least the past fifteen years? I was surprised by the willingness among those around me not only to openly express contempt for “consumers” of such meats, but also for consumers more generally - especially given the conservative, market-focused cultures of production that dominated the commercial environments I conducted my research within.

Gradually, between snarky asides about customers “projecting their human issues onto their pets” and buying ‘responsible cat food,’ derisive invocations of clueless consumers, misled by a biased media system into “organic” or “ethically-sourced” purchasing habits, and farmer-owner frustrations with pressures from grocery chains and food manufacturers to operate in specific ways, a context began to emerge. The open hostility I saw for “the consumer” appeared to be an expression of currently shifting power relations and behavioral tendencies between the people who purchase food, the people who grow it, and the people who process and sell it. This frustration or hostility often appeared to function as a kind of culturally identifying gesture or invocation, thrown out to see whether one ‘got it,’ was on your side, knew what you knew.

This also went some way towards explaining the explicit the pledges of allegiance to “capitalism” and the market that would happen during presentations, conversations, and interviews which I also found confusing, if intriguing. I frequently heard some point or question prefaced with “I am a good capitalist, but-”, ‘as a good republican,’ ‘I believe in the market.’

Why, given the relative political homogeneity among the large food producers, agricultural researchers, and farmers I spoke with, did they feel a need to so explicitly insist on their faith and loyalty to the liberal market society?

The answer, in part, had to do with what Nestle executive Patricia Stroup described during a 2018 talk at Purdue as a "new and sort of irritating phenomenon:" the rising importance of securing "consumer trust" that from this perspective is increasingly dictating not only what was grown, but how. The friction here hinged on a perception held by many US agri-system producers and processors that, basically, consumers are ignorant yet entitled, and fooled by agenda-driven media companies and education systems have been misled into misplaced and incorrect beliefs about American farms and food production. As one Midwestern farmer put it, "there is this push that they want to know where their food is coming from. I think a lot of females do your grocery shopping for their families and they want to make sure that the food that they're buying for their children is healthy and not going to harm them. And the media outlets have kind of instilled this fear that our food is being grown in an unhealthy way."

Yet because such farm owners and executives present themselves as "good capitalists," they have to respond to such market pressures and desires, even if they are frivolous and do not command respect. In Stroup's words, "I believe in self-regulation, I'm a free market economist, I'm very much 'get the government out of our business, but consumers still hold us to [accountability].' The banking crisis has destroyed consumer trust in things, so companies need to adapt to consumer issues."

Achieving, which is to say producing, consumer trust in a given food product today means creating "transparency and traceability" in the agricultural supply chain, traits that extend to and reach across producers, purchasers and brokers, food processors, and grocery stores.

“Transparency” refers to the process of making food properties, food production practices, and movement of products through a given agricultural supply chain evident and available to interested parties through the capture and transmission of data about those processes and the movement of agricultural commodities. “Traceability” is the systemic documentation and tracking of a given product’s history, from its place of origin through the supply chain to its sale, by way of the generation, collection, and communication of information about whatever product.

The importance of “transparency and traceability” moving forward was something regularly touched on by the people I spoke with throughout my fieldwork. An agricultural economist at a USDA Extension office I spoke with told me that in her circles, this was seen as “the next big thing in food;” similarly, a prominent Western New York farmer told me that in his experience “traceability has gotten to be such a big thing … that's just something that's here. It's going to stay. It's going to get even higher. There's going to be more traceability down the road. They want to know exactly where every can, where every box of corn came from.”

The drivers of transparency and traceability initiatives were frequently framed as first and foremost consequences of contemporary cultural and even generational changes among consumers. Ask a “Boomer” to jump, I was told by one ag conference presenter, and they’ll ask how high; a “Millennial” by contrast will ask “why?” This was offered as evidence of the frustrating and problematic mindset of contemporary consumers, especially those removed from any direct experience of how their food is produced: “a lot of consumers don’t know anything about where their food is grown,” I was told, yet Americans paradoxically want “more information about where the food’s coming from.” “It doesn’t matter what we [in the industry] think” when in America today, these fake-meat-eating people’s “pets are their babies, [and] they expect the same things for their cats as they do their babies;" namely 'responsibly sourced' and 'ethically produced' cat food.

Yet the picture appears to be growing more complex. The perception that identity marketing resonates with today's consumers has driven changes in the actual commercial relationships structuring the actions of major food corporations. Shareholders in food corporations are "investing in companies who have this ability to be able to connect with consumers and be able to operationalize that need;" and because such corporations are "not a charity, our mission is to return value to shareholders," investments in traceability and transparency were not simply an annoying trend, they increasingly represent a financial necessity.

It is worth noting, if only in passing, that these trends and perceptions harken back to the genealogy of *precision* undertaken in Chapter 1. Here, however, it is precision as *personalization* that comes into view: mediated customer targeting and 'segmentation' are crucial economic and socio-technical elements of such a commercial marketing and advertising system, organized by and around dividuated identity coordinates. Here the 'precision' data gathered about a field of soybeans or a "free range" chicken is explicitly translated by transparency and traceability imperatives into 'precision' marketing indices.

Ultimately, supply chain traceability and transparency boil down to a number of affordances and benefits members of the agri-food industry and related government agencies see them as providing. Agricultural data offer the ability to provenance food, and track it to is origins, a foundational step in this epistemological 'trust building' process. It is used to authenticate claims our doubts about provenance or production methods, product traits and so on; in other words, is this food produced in a specific way, in a specific place, and is can it be verified? Traceability and transparency are also part of efforts to more tightly and accurately track food along the supply chain for health and safety purposes, namely for food recalls and identifying problem sources. More fundamentally, agricultural data used for tracking translates into ‘value additions’ and higher profitability for actors across the supply chain, some of whom (like farmers or grocers) will be paid more for “local,” “organic,” “fair trade,” and similarly certified food products whose additional ‘ethical’ components not only require additional complications and steps to a given production process, but certification processes that can add time and costs. Farmers in particular are eager to see gains from their investments in such methods. Agricultura data tracking infrastructures also promise to be integral to insurance against a variety of risks for agents across the ag supply chain, as well as creating purchase for new or more intensive regulation and compliance opportunities – whether corporate or governmental – offering tighter accounting of product histories that could play a role in controlling or buffering risks or bad press from, say, food recalls or labor issues (e.g. crackdowns on “undocumented” labor on farms, or child/slave labor in the food system).

The global commercial supply of organic crops is illustrative of this latter point. The United States is generally the leading global producer of soybeans, and produces more corn by far than any other nation on the planet, but the overwhelming majority of those crops are produced conventionally – genetically modified, grown with herbicides, pesticides, synthetic fertilizers, etc. – not certified organic. Consequently, the domestic market for food made with or using organic corn or soy, whether for direct human consumption or as a means to certify chickens or other species fed with this corn and slaughtered for food as ‘organic,’ is limited. Nations like Turkey and the Ukraine have lately been shipping organic soy and corn *to* the United States as producers have been slow to catch up with demand. In 2017, a shipment of 36 million pounds of conventionally grown soybeans from the Ukraine and Turkey ended up in California having, somewhere along the way, transformed into “USDA organic” certified soy (Whoriskey 2017). This alchemical shift boosted the shipment’s value by over $4 million, and by the time red flags were raised over 21 million pounds had already been distributed and sold to American consumers (largely for animal feed; Whoriskey 2017). Similar metamorphoses occurred with two other large crop shipments that year (both 46 million pounds of corn from Romania brokered through Turkey), constituting a not insignificant proportion of the US supplies for that year. Certification for these shipments appears to consist of a mix of documents, agreements, and other media. Proponents of transparency and traceability programs in agriculture see the datafication of farming and digitation of commodity records as a boon that would help eliminate such fraud, insuring companies from risk and consumers from malfeasance, while helping to identify bad players and regulate global trade more effectively.

In short, the hinge upon which both the obsessions with fake meat and the concern to espouse one’s allegiance to capitalist swing ultimately emerged in my research as consumer trends in food consumption, in this case specifically in terms of “ethical” and “responsibly sourced” food. These trends, due to their nature, intrinsically place demands upon food producers, manufacturers, and retailers to change what they make, how they make it, how they process it, and what they stock, sell, and market. To ensure such agricultural responsibility, which is to say to ensure trust in a market system ostensibly organized around principles of free trade, competitive advantage, and invisible hands, a system that has grown enormously complex and global in scale, transparency and traceability boils down ultimately to the dream of joining word to deed, of guaranteeing oaths of provenance or process through the necessary quantum of data.

How could such guarantees be achieved? The datafication of farming initiated by precision agriculture over the past several decades has created essential precondition for several possibilities; one of the most popular answers that has emerged in the past few years has been the implementation of blockchain ledgers in the agricultural supply chain. Authentication by blockchain is hailed as an ironclad solution to such issues, and a powerful step towards the implementation of true supply chain transparency and traceability. It has the appearance of tamperproof-ness, which is why it is hailed as the next step in supply chain – and so agricultural – governance. This is of course despite the serious environmental and infrastructural costs this technology currently and intrinsically incur; guaranteeing and transmitting the specific qualities of a product that ensure its market value and position offer advantages that seem to push any such concerns to the periphery. I certainly never heard anyone raise the issue of energy costs or rare earth minerals when and where blockchain technology was discussed. Regardless of the method by which transparency and/or traceability are achieved, however, my observations, interviews, and literature reviews have made it clear that the dataveillance of agricultural commodities represented by traceability and transparency initiatives are widely viewed as inevitable, necessary, and soon to be universal. This is yet another way in which it becomes clear that precision agriculture – the birth of the data farm, the datafication of farming – is in core respects not especially about *data* or digital technology, regardless of the fetishization of data and drones that characterize it, but is about maintaining a particular socio-economic order, keeping the systems and relationships that organize the market system and its beneficiaries in place.

So far I have presented this discussion in terms of the 'supply chain' in abstract, but following from this last point there are specific relationships within its links that deserve closer attention. Specifically, this tension between perceived consumer demands and cultural trends on the one hand, and the introduction of traceability apparatuses into the food and farming system on the other. The source, in other words, for these explicit pledges of allegiance to capitalism appeared to be a tension felt by people across the agri-food production system – including several government officials that I interviewed – between their feeling that consumer demands for ethical, organic, local, or fair-trade food were intrinsically stupid, misinformed, or malicious, and their allegiance to a worldview where consumer desires drive producer behaviors. This pressure on producers, however – these "market forces" – appeared to be most directly felt not through some unmediated relation between average consumers and any given farmer, but in the form of what are ultimately regulatory pressures placed on farmers not directly by the public or governments, but private corporations and industrial associations. These corporations are quick to frame their actions in these terms; as one put it during a conference talk at Purdue in 2018, "when we come to you [farmers], we need traceability; it's not because we don't trust you, it's because the consumer doesn't trust you."

The combination of an understanding of the growth and availability of multiple forms and granularities of agricultural data with demands for more ethical, "natural," or responsible food production – in terms of labor, environment, and/or food qualities – has produced a situation in which corporations with commercial interests in food production are increasingly placing explicit production demands on growers, and monitoring/certifying those demands with digital means. In short, farmers are under increasingly powerful and multi-faceted forms of dataveillance, beyond those of the equipment suppliers and data processors producing and maintaining their precision agriculture systems and machines.

I found a talk I attended by Nestle's Global Vice President and Head of Commodities Patricia Stroup especially revealing on this score. Stroup (2018) stressed the pressure companies like Nestle felt from consumers, non-governmental organizations (NGOs; it was contextually clear she largely meant labor and environmentally-focused nonprofits by this), and states, to make specific changes and develop particular technologies for implementing greater supply chain transparency and traceability. She began her talk by emphasizing the consumer and cultural shifts in food marketing, where consumption is explicitly tied to identity and personal style, something that translates to shopping choices both in terms of retailers (e.g., Whole Foods vs. Walmart), and choices in terms of products (e.g. organic vs. not). She, like many others, stressed the ignorance of modern consumers regarding conventional production, using American's relationships to their pets and pet food purchases as a direct line to the kinds of "trust" issues in the supply chain greater traceability would solve. If, for example, Nestle was purchasing "26 million tons of raw seafood from 150,000 direct suppliers" in Southeast Asia for their cat food brands, "how do you logistically trace the catfood sourcing" in order to assure such consumers that it was not only ethically produced, but produced using ethical labor?

This last point touched on some of the scandals Nestle has faced in the past decades over the uses of slavery and child labor in production of materials they procure for manufacturing. She cautioned the audience that "if you're going to do transparency, you have to be willing to face what you're going to find … when you talk about transparency, be careful what you ask for because you're going to find things. What happened in the past was it used to be, 'I don't want to look, because I don't want to know. If I don't look, I don't have to address it. Consumers aren't letting us make that choice anymore." Nestle, for instance, infamously (if ostensibly 'indirectly') supported and benefitted from child labor on West African cocoa plantations, and discovered "slavery issues" among their Thailand seafood suppliers, which according to Stroup they addressed – and then publicized – "because consumers have to know what we're doing."[27] These issues aren't limited to foreign supply chain sources either, as despite the "sophistication" of US farming systems, "when you do the management you're going to find things, violations of overtime, undocumented labor, environmental issues" and therefore must have plans in place to address such issues.

Stroup provided an example of such plans in action using Nestle's approach to deforestation in palm oil sourcing, where Nestle is "using satellite imagery *to track and police a little better what's going on* around these commitments our suppliers make to us" (italics mine). According to Stroup, deforestation for conversion of land to palm oil production had been a "huge issue" in the recent past, with Greenpeace 'going after' Nestle as a large and representative company to do something about the environmental damage in their supply chain. "Logically," she said, "we're not the largest part of the palm oil problem, but it doesn't matter what we think, it matters what the consumer thinks. Even if they don't know the whole story, don't have all the answers, it doesn't matter because we're not the ones buying our product, they're the ones buying our product." Consequently, Nestle has adopted a series of measures to "police a little better" their palm oil suppliers, including satellite imaging of forest and palm oil lots, using images for surveillance of supplier activities, to ensure compliance with Nestle's corporate policies. Stroup offered an anecdote of this system's efficacy, where upon discovering a supplier that would not stop the deforestation their organization was causing they stopped buying from them, eventually encouraging that supplier to "come back to the fold." This was an

[27] Earlier this year, the US Supreme Court blocked a lawsuit brought by several former child slaves on cocoa plantations against Nestle and Cargill, arguing that because the abuse occurred outside of US jurisdictions, the suit had no legal standing, and the companies could not be held responsible in US courts. *Nestle USA Inc. vs. Doe et al.*, No 19–416, slip op at 1 (US Supreme Court June 17, 2021).

approach and technology that Stroup highlighted as something that could in general be "used for a lot of things."

This increased, digitized and mediated governance of suppliers – whether of palm oil, "beef" cattle, or soybeans – is the crux of the issue of transparency and tracing I highlight using a few examples drawn from field research below. This issue involves the ways in which agricultural digitization introduces not only the conditions of possibility for such tracing and tracking, but of new intensities and opportunities for *governance* more generally. The farmer in Kansas I spoke with put the issue this way: "The goal is that Walmart can sell to an end consumer. Well how does the end consumer know it was farmed with no fertilizer?" In a conversation later that day, one attendee of the conference at which Stroup spoke, a food manufacturing executive, shared his thoughts with me about the implications of such supply chain governance. He emphasized that increasingly companies like Nestle, Walmart, and Kraft – among others – will only demand more, and more kinds of data from their suppliers moving forward; "to do business with Nestle," he said, "you'll need to have the kind of infrastructure." Or in Stroup's own words, "this is the new norm. There was big pushback from farmers against companies making demands on how things are sourced – we still have things like that in the meat industry, 'you're not gonna tell me how to treat my cattle, you're not gonna tell me how to trace', but that is slowly changing." "Be willing to disclose everything," she advised the audience; "you can't be half pregnant."

This issue was a serious concern and point of contention for many farmers I spoke with across the country, especially when corporate dataveillance and "policing" was seen as lopsided and extractive, offering no value passed on to the farmers being, as they saw it, constrained by unfair and misinformed market forces. The farmer I interviewed in central Ohio was fairly optimistic, seeing the beginnings of

> opportunities through some of your larger industries, where I think we'll see premium opportunities to be able to provide information saying, you know, here's … everything that's went on. Basically, traceability; if you're able to trace back to see where that corn exactly came from, whether it's, you know, a large dairy that wants to be able to kind of roll out and say, "We fed our cows this and it was all non-GMO," you know, "Ten percent less nitrogen," all these different things. I think that that's coming pretty quickly, which is why we made the decision in 2014 to work with Granular because we wanted to be able to give somebody that information.

Yet even she held reservations as well, using Walmart as an example of the imbalance of power and benefits many farmers appear to experience:

> … they're watching everything that's coming off their shelves and they're very data-driven. And if they're starting to see, oh, you know, 'non-GMO green beans' … are being bought more than this other green bean or whatever it is, then they're going to start demanding [them]. The part that's a little bit frustrating at times is, a lot of times there's premiums that are offered, but sometimes there's been things that have been pushed down to us that we have to grow-- do certain things a certain way - but there's no price benefit for the grower, and I think that's where the gap is right now.

Many others I spoke with shared precisely these concerns. One New York farmer explained their objections in similar terms of imbalances in profit and power:

> …you could say, okay, with all this animal care, employee care, sustainability requirements, everything that the big food companies – we just saw Nestle, Unilever, the big four just announce they've broken away from the Grocery Manufacturers Association, they're going to have their own little thing, they're going to have their own sustainability requirements and everything –…so if [they] want this from us, you want to know precisely where the food's coming from, how it was raised, are you willing to pay for it? And so far the answer is no, because there's enough people willing to give it to them [for free] I guess. I mean if it was me, I'd say … "Okay, can we go to a cheese manufacturer that's taking our milk every day, and would they pay us to be their model farm?" … if we're willing to open our door and allow you to showcase how milk is produced to [the public], then is there a value?"

Another farmer expressed similar feelings, asking

> Who's going to see this? Is it going to cause me more headaches? I mean, that's the problem: no one will tell the farmers what they want the information for. But none of us out here are that stupid. I mean, you see the policies, you listen to stuff; we know what they want it for. They want to start tracing everything down to the nth degree, which is fine, but we don't get paid for it. But then they want to fine us … it's just [that] not everybody is there yet [i.e. generating traceable data]. The industry itself, they want to be, but it's a financial burden until people are willing to pay for it.

One phenomenon related to these concerns that emerged during my research that I found particularly interesting and important, but that I could not integrate into this present, fairly broadly-focused study: the role of data in making US agriculture increasingly comprehensible to, and attractive for, the financial industry. There is a great deal to cover here, from the increasing role of Wall Street in farmland ownership and agricultural investment, to the digitization of the agricultural commodities supply chain, to efforts in implementing the theory of ecosystem services. There is an excellent and substantial critical literature on financialization in agriculture that has grown significantly in recent years. However, this literature has not yet, as far as I have seen, dedicated enough attention to importance of digital technology in contemporary financialization processes. Based on my research I believe there is good reason to focus on the roles that agricultural data, computation, and mediation play in the process of making farming attractive to new kinds of capital, in addition to and beyond the banks, loaning institutions, investors, and insurance agencies that have traditionally been insinuated with American agriculture. Indeed, one interviewee highlighted the ways in which issues of market forces, industrial supply chain governance, the financial industry's growing interest in farming, and environmental regulation are insinuated with one another as agricultural data becomes more common, variegated, standardized, and accumulates into histories.

> I think we'll start to see a push [where] they want less inputs but they want to see a cover crop, they want no till. I think that there's different investment groups that I can foresee coming down the pipeline and saying, you know, you can farm this ground but you have to be able to provide this information to me, and also, you're only allowed to do X, Y and Z on [it].

This brings us to a final point of consideration regarding agricultural data and traceability initiatives. Beyond questions of corporate power, of the increasing *private* regulatory and governmental power held by food manufacturers and retailers mining data and profit from precision farming American growers, farmers were also explicitly concerned with the opportunities for more intensive and granular *state* surveillance of their operations data farming creates. Many expressed concern for the environment generally, while also dismissing critical accounts of conventional farming as misguided and misinformed. Most of my interviewees seemed passively interested in the potential environmental benefits of precision agriculture, but for almost everyone these benefits were in no way a motivating reason for adopting PA equipment, nor a central concern for their operations. For many, however, the knock-on effects of both greater amounts of data, and their lack of control over how that data is used and who has access to it, did raise specific concerns regarding government intervention in their operations in the name of environmental policy enforcement. One farmer in the Great Plains voiced such concerns to me explicitly:

> … whoever has access to this data, it's dangerous information … I mean, like, if the wrong people-- got in the hands of the Environmental Protection Agency or wildlife and parks-- I mean, they could ruin farming. I mean, they could go to an individual farm and say, "I saw you put too much nitrogen on the field, it shows right there in that map, you did it. You're going to pay us back for the damages you caused." Right? And that's where [it] is with the corporate world, right? You know, if companies get out of line, they get fined.

This study began with an interest and focus on hardware and physical platforms that appeared to play a growing role in the digitization of agriculture. That focus quickly produced a recognition of the benefits of many such technologies, whether they be row/spray control systems, autosteering, or new kinds of remote sensing equipment, as they applied to the existing conventional milieu of capitalist, industrialized, monocropping agriculture for the production and marketing of standardized food commodities. Yet over the course of this research, another dimension of that digitization has emerged more and more prominently. The efforts to maximize yield, make rows more efficient, or reorganize the land more profitably have created for many what amounts to a relatively unanticipated, unplanned for, unforeseen milieu where because the data such activities hinge upon now exists, and because it creates the conditions of possibility for matching sources of food and methods of farming to manufacturing/processing trends and retail marketing, something like a recursive cycle fueled by that data appears to be picking up speed. The data begets conditions for surveillance and governance beneficial to farmers, the agricultural industry, food manufacturers, and grocery retailers, which exerts pressures on all involved to increasingly adopt the kinds of technologies to generate and manage such data, which in turn drives efforts to generate, refine, and circulate more and more of that data.

Transparency, traceability, governance, policing: it is clear that the advent of the data farm generates much more than material and economic savings, efficiencies, and other mechanical affordances. Equally evident is that the futurist imaginaries and informatic ideals precision agriculture both feeds and is fed by are not the limits of its produce. In other words, one of the more significant consequences of agricultural digitization highlighted by my fieldwork and research appears to be a new degree and intensity of, a new step in a long process of what in the next and final section I will characterize as the dream and attempt to introduce the "government of nature." This is government includes and in many ways is founded upon – but as we have already seen is by no means limited to – the precision agriculture-using farmer mediating the lands and phenomena under their power, like a sovereign or governor in miniature, a landlord organizing the oikos of their property and operations. It is also a government of nature in terms of the government of "supply chains," a private regulatory apparatus that is international in scope and power, along with the traditional "ecological sovereignty" of the nation-state itself (Smith 2011), an "environmentality" (Agrawal 2005) that translates to direct consequences for laborers, economies, and environments.

IV. The Government of Nature: Code as Law as *Police des Grains*

This discussion of traceability and transparency above rounds out the final chapter of this study of precision agriculture by pointing to the rising significance of data, information, and *government/regulation* – both public and private – in farming. It should perhaps not be too surprising that, contrary to the sparkling perpetuum mobile of a [counter] revolutionary, informatic future, at once linear *and* eternally repeated using endless and ingeniously reaped agricultural efficiencies, the reality of the data farm looks much more like corporate and state bureaucrats consulting digital spreadsheets, holding meetings, making calls, issuing fines to farmer-owners who do not comply with their policies – crop and cow managers who in turn essay to invent new frontiers of accumulation wherever they can, squeezing their labor, land, chattels, cattle, and capital ever more tightly for their last shrinking motes of productive return.[28] In other words, when one pauses to consider, as Jon Agar deftly has, that the computer is the "government machine" *par excellence*, and that digital technology represents first, foremost, and above all "the apotheosis of the civil servant" (2003, 3), it should perhaps be obvious that the face of precision agriculture is the banal yet threatening mien of policy, code, regulation: in short, of government.

Consequently, the preceding discussion of transparency and traceability on the data farm in this chapter, when taken together with (a) Chapter 1's consideration of the "mediation of nature," (b) Chapter 2's description of precision agriculture as an apparatus of informatic ontology, and (c) Chapter 3's historicization of precision agriculture as an informatic ideal rooted in long-unfolding imperatives of capital and state, points to what amounts to a new step, or degree of intensity, in what I call the "government of nature." Which is to say first and foremost the *effort*, the *dream*, the *desire* for a government of nature, the command and control of ecology, not the actual achievement of such any such thing. But more on that to follow.

First, one could reasonably object that the 'government of nature' is hardly a new phenomenon, but part of a tradition that stretches back at *least* five centuries, if not beyond. They would certainly be correct. James Scott's (e.g. 1998) studies of government and its technologies are likely the most prominent, but hardly the only example of an even longer history of the

[28] Here I am implicitly invoking the contrast of natural cycles with rational modernist repetitions, as outlined in 1987 by Henri Lefebvre in "The Everyday and Everydayness," trans. Christian Leach, *Yale French Studies* 73: 10.

government of nature as the nature of government. In many respects any and every institutional government, given that technology's absolute indebtedness to agriculture for its conditions of existence, could potentially always be considered government of nature.

From another perspective, Michel Foucault's (2007) discussion of the birth of an influential "anti-Machiavellian" literature concerned with the development of an "art of government" that emerged in the 16th century is perhaps the most famous contemporary example of this lineage. Drawing on this account to highlight this genealogy of government as it relates to farming will shed light on why what I call the introduction of an informatic ideal in farming – precision agriculture – represents a specific kind of contemporary step situated within a context of much older endeavors towards a comprehensive government – and so control – of nature.

The general Christian Medieval tradition of European divine sovereignty out of which early modernity developed was one that modeled the king as *pater familias* to the *oikos* of his realm – that is, the subjects and territories of his household under his paternal protection and care (e.g. Kantorowicz 1957). This figure of the king as governor vs. the king as Prince was, in these political orthographies, a king that governed a household vs. an individual possessor of a property; he was a divinely appointed father-in-lieu-of-The-Father to an *oikos*, whose welfare and flourishing was consequently his responsibility to establish and maintain. This was the ancient practice of *oikonomia*, or "economy," the good and just government of the family and household to ensure its welfare as a model for government of the state itself, patterned over the Christian architecture of a paternal God shepherding his earthly children; the "supreme victualer" who nourished his children, as Kaplan (1976a, 5) put it in his landmark study.

In other words, in the philosophical and political tradition emerging at this time, where the theme and model of government becomes one of "the introduction of economy into political practice" (Foucault 2007, 95), the articulation and development of a theory of *political œconomie* that emerged subsequently had a profound and lasting influence on the political organization of sovereign government in the Western tradition. Within this institution of *political œconomie* or the art of government, moreover, one was not simply assigned govern territories or subjects in the more strictly medieval, Machiavellian respect, but governed "*things*," a "complex" that involved things like

> [human] relationships, bonds, and complex involvements with things like wealth, *resources, means of subsistence, and, of course, the territory with its borders, qualities, climate, dryness, fertility, and so on.* "Things" are [people] in their relationships with things like customs, habits, ways of acting and thinking. Finally, they are [people] in their relationships with things like accidents, misfortunes, famine, epidemics, and death. (Foucault 2007, 96), emphasis mine.

In his discussion of governmentality, Foucault mentions that the "metaphor of the ship" is inevitably invoked as a model for government, wherein government of a ship means the "practice of establishing relations between the sailors, the vessel, which must be safeguarded, the cargo, which must be brought to port, *and their relations with all those eventualities like winds, reefs, storms and so on"* (2007, 97; italics mine). Not only does the way Foucault phrases this bring into question whether or not he was aware that "government" literally means "the steering of a ship," his analysis repeatedly highlights the importance of that which would later become known, depending on time and context, as "nature's œconomy," "environment," or "ecology" to government itself (on 'nature's economy' see Worster 1994). In other words, the birth of modern governmentality intrinsically represented the birth of an explicit theory of a government of nature.

Just as importantly, the development of a *political œconomie* from the end of the 1400s onward marked the appearance of a new technology for achieving this very government of "men and things" toward their "good order" and welfare: the technology of *police*. *Police*, or in the original French-Burgundian *policie* "spread across Continental Europe and generated a range of words" over the 16th century, including "*Policei', 'Pollicei', 'Policey', 'Pollicey', 'Pollizey', 'Pollizei', 'Politzey', 'Pollucey'*, and '*Pullucey*'" (Neocleous 2000, 1). The ambiguity of this word should be immediately apparent through these prismatic inflections – it at once looks and sounds like both "police" and "policy." This is because these words are twins, kin and cognates that both derive from this original linguistic apparatus as it grew in popularity over the 16th century. *Police* and its variations/derivations were due in part to the ways in which Aristotle's *Politics* was translated from the 13th century, particularly in France and Germany where "key terms of Aristotle's text – *polis* and *politeia* – were often translated as 'police'" (Neocleous 2000, 11). In England, by contrast, these terms were usually translated as "Commonwealth" or "policy," marking a split in terminology – but not in epistemological architecture – between continental Europe and the British isles that would only resolve with the importation of *police* through the influence of French and German "Mercantilist" and "Cameralist" political principles during the 18th century, as evidenced in, for instance, the earlier works of Adam Smith. Police would, in the Anglophone world and elsewhere, evolve into its stricter modern sense of "law enforcement" not long thereafter, and by the end of the 19th century a new concept – that of "the" police – had grown dominant in the United States as in England. But *police*'s genealogical inheritances have never ceased haunting its modern articulation, and the same histories that informed what came to be known as the "science of police" in 17th century Europe continue to possess the figure of the modern police *officer*; a *camera*, as in Cameralism, literally signifies an *office*, after all (for more on this modern liberal capitalist history of the modern police "force" and carceral state, as well as the legal foundations of the liberal "police power," refer to Dubber 2005 and Harcourt 2012).

Police was, in short, the term that designated the application of *political œconomy* to the administration of the affairs of a state. The flickering quantum status of this word throughout European and related, imperially-influenced histories, existing as two seemingly distinct apparatuses – *police* and *policy* – discovers a basic reality of police/policy as one another's obverse, two technologies of government mutually organized by and as information, codes, and the enforcement of strictures. The question arises, however: why does this anti-Machiavellian literature from which modern government and *political œconomy* derive, at the heart of which sits the question of how to govern well, emerge when it does during the 16th century? In other words, one might ask 'why does the figure of *police* suddenly appear so widely and emphatically across Europe during this time?'

To gloss a complex reality, the answer involves the loosening threads of feudal relations, particularly in England, and this processes' various links to a collection of socio-political phenomena then simultaneously, if unevenly, unfolding across Europe These included 1. the advent of new and increasingly international commercial relations and systems in Europe, including a nascent capitalist system located at first largely in England, that catalyzed a movement towards the privatization of land which increasingly forced people off of their land and threatened the establish social order of feudal Europe from the 15th century onward, 2. the many social consequences of the Black Plague, and 3. the "disorders" of serious and numerous peasant uprisings throughout Europe over the previous two centuries. In other words, from the perspective of the ruling classes, the world was increasingly disorderly, characterized by a violent peasantry and rising tide of beggars and vagabondage. As such, new measures were required to reestablish order and maintain social hierarchy, stability, and its existing organization. These measures were those of *police*.

Police practices as they emerged during this initial period were effectively "conservative" in a literal sense, designed to retain, re-establish, and maintain the essence of the social order as it had existed up to that point in feudal Europe. This order was evidently increasingly unraveling, multiply threatened by the very actions of social elites that sought to preserve it: generally speaking, land enclosure and privatization, measures of productive rationalization, and improvement initiatives. Such actions contributed to the development of towns, the complication of commercial tableaus, an increase in forced or chosen mobility – physical as well as social – that in turn had threatening and disorienting social consequences from the perspective of the aristocracy and their epigones. A growth in towns, in "night-life," in new opportunities for the generation of wealth and so of consumption, congregation, and 'morally' threatening changes in ordinary social and cultural life in general (drinking, sex, political activity, 'blasphemy,' 'idleness,'), in addition to violent and at times temporarily successful peasant and religious revolts all characterized immediate threats to the order upon which the nobility and elements of a commercially ascendant bourgeois (i.e. people of the burgh vs. people of the heath; burghers, city-people, town-dwellers, *not* 'the ruling classes' as such) depended (Kaplan 1976a; Neocleous 2000; Foucault 2007; Koslofsky 2011). *Police* at this stage was at once the name for the goals ("welfare" and "good order"), objects (communities, the "polis"), and the actions (*police* measures) taken to organize and direct communities under police authority derived from a patriarchal sovereign charged with establishing the just and orderly dispensation of his kingdom/*oikos*. Consequently we can see that "from the outset police was for the most part concerned not with criminal activity but with activities potentially damaging to communal good order. In other words, preventing crime was not integral to the definition of police; crime prevention has never been the *raison d'être* of police" (Neocleous 2000, 4). To the contrary, the focus of *police* was, and remains, the government of men and things, the establishment and maintenance of a particular order, and the prevention of disruption to it, the establishment of a security *from* or *against* threats to that order.

Police ordinances of this initial, largely conservative type for regulating the immoral and disorderly state proliferated over the 16th century. But from the turn of the 17th century and onward, this emphasis would undergo important shifts and evolutions, significant to the history I am tracing here, in which the character and purposes of police transformed from chiefly the restoration of specific orders to more literally positive ends, particularly those of the prosperity, welfare, and what was called "police and good order" of the kingdom (Raeff 1983). Over the 1600s the technology of police transformed into a positive force, in the literal sense of "positive law," an apparatus designed to implement the measures that would not only maintain order, but organize society in such a way as to most judiciously increase its splendor – and so with it, that of its sovereign. Crucially, such changes were

> linked to a set of analyses and forms of knowledge that … [were] essentially knowledge of the state in its different elements, dimensions, and the factors of its strength, which was called, precisely, "statistics," meaning science of the state … we cannot fail to link this search for an art of government with mercantilism and cameralism, which are efforts to rationalize the exercise of power, precisely in terms of the knowledge acquired through statistics (Foucault 2007, 100-101).

In short, monarchs discovered that natural philosophy could be useful to royal power in its efforts to see and know, through mapping, geology, agricultural science, geology, and so on. Science offered "*Staatsbrille*" through which a sovereign could perceive what was necessary in order to govern 'men and things,' including the techniques that would develop into the technologies of statistics and the identification and management of populations. In England, where the actual term *police* did not come into fashion until the later 1700s, a literature of agricultural improvement exploded across the 17th century. This literature identified agriculture as the "basis of a peaceful and prosperous kingdom," coloring it with a moral character of use to the sovereign: namely, as a Christian means for improving men's souls, and through them the state; a rationalized and improved agriculture could also, incidentally, "toughen yeomen into material fit for an army" (Drayton 2000, 51). In short, "a king, a statesman, or a colonial governor could also come to be construed as a divinely appointed gardener" (Drayton 2000, 68). As noted in Chapter 1, the project of imperialism taken up and pursued in earnest by England at this time – most pointedly and systematically perfected in Ireland over the 17th century – served precisely as an extension of this ethic of improvement; the scope was merely extended to the enclosure and improvement of the 'wastes' world itself, instead of simply England.

The "alliance" of the monarchical state with the *philosophes* and *savants* during the 17th century was pursued most systematically, however, in central European states like France and the principalities of the Holy Roman Empire. Following the ruin of the 30 Year's War, systems of "mercantilism" and "Cameralism" developed explicitly to advance and implement what became known as the "science of police" and the "police/y state," a rationalized, scientific approach to provisioning happiness and wealth – welfare – for a kingdom (Drayton 2000, 68). "Political economy," e.g. "the introduction of economy into political practices" and *police* constituted fields of inquiry in common within the Cameralist system, which is why "objects found under the heading of *Cameralwissenschaft* are also found under *Œconomy* … Police theorists therefore recognized the diversity of social life and the importance of productive and active economic performance, but sought to draw them both into a unity. It is for this reason that the same objects are found under 'cameralism', 'Oeconomie' and 'Police" (Neocleous 2000, 13).

Within this context, a body of *polizeiwissenschaft* or "police science" ordinances and regulations addressed specifically to agriculture evolved into a practice known as the *police des grain*, "police of grain," by the turn of the 18th century. A key purpose of introducing economy into government, and is execution *qua* police, was to more effectively prevent the most extreme and undesirable form of disorder – outright revolt – a species of unrest that agricultural dearth or famine in particular could dependably precipitate (Kaplan 1976a; Raeff 1983; Foucault 2007). This was ostensibly to be achieved by a strict and careful regulation of all possible dimensions of the production of and commerce in crops. The *police des grains* employed codexes, codes and constables, policies and police, to regulate seemingly every facet of agricultural production and trade: how, where, and by whom food was grown; how it was processed, transported, stored; who sold it, when, where, and at what prices, and more (Kaplan 1976a, 1976b; Harcourt 2011).

Consequently, it is possible to see how not only police/policy themselves, but agricultural ordinances in particular were from their beginning a central part of this burgeoning art of government and the *political œconomy* it spurred. Famine or dearth would hardly threaten the king, so in this sense the early purpose of the police of grain was not to prevent death from hunger for *anyone per se*, but to eliminate the conditions of revolution and foreclose the kinds of peasant revolts such hunger might fuel (Raeff 1983). Dearth, furthermore, sapped productive power by weakening, incapacitating, or killing laborers, in turn reducing the power and splendor of the state and its monarch. As these were central objects of Mercantilist and Cameralist "police sciences" aimed at provisioning and strengthening the state, the *police des grains* that emerged toward the end of the 17th century was aimed explicitly at encouraging such welfare and prosperity through a literal and extensive grain police force.

The efforts to employ police science towards the production of a "well-ordered police state," one of clockwork-like mechanization and efficiency that sought to ensure everything functioned correctly, in its right, place for the benefit of all, ultimately led to a proliferation of regulations. These grew so numerous by the 18th century that they spawned a miniature literature consisting of compendiums of police regulations, including Delamare's famous 1705, *Traité de la police*, Duchense's 1757 *Code de la police, ou analyse des réglemens de police, divis*é *en douze titres*, as well as M. Edme de la Poix de Fréminville, 1758 *Dictionnaire ou traite de la police géneralé* and his agriculturally focused, anonymously published 1753 *Essai sur la police géneralé des grains, sur leurs prix, &c*, among several others.

Particularly in France, this proliferation of police regulations was increasingly perceived and presented as burdensome, oppressive, as well as *misguided* by a growing and influential group of government officials and natural philosophers, among the most prominent of which was the *economiste* and Physiocrat François Quesnay, physician to King Louis the XV. Under Quesnay, "economy" becomes its own object in the more modern sense under Quesnay in 18th century France, becoming more specifically and precisely concerned with phenomena of production, consumption, commerce, trade, wealth, finance, population, labor, and so on. The key intervention of the Physiocrats was the introduction of a new kind of appeal to nature, and a natural order, into the "economy" at the heart of modern governmentality.

Quesnay's dream was one of an "economic government," a theory of *economy* in which the word and concept of at this point begins to take on its more modern meaning, shifting from a signifier for what Foucault points out would be tautologically equivalent to "government," to designate the more specific phenomena mentioned above (2007). From this point forward, "the" economy represents increasingly privileged site of intervention for the establishment of "good government," vs. the 'household' writ large (literally so, in the burgeoning indices of police regulations).

The full phrase Quesnay used for designating this vision, however, was an "economic government *of an agricultural kingdom*." For the Physiocrats – a name that literally means the ‘rule of nature’ – all value derived ultimately from agricultural labor. Quesnay and other Physiocrats tied a political philosophy and police science to the notion of a principle of nature, using science to 1. Discover the natural rules and realities of existence, as ordained by God, and 2. Given their divine ordination, use these rules and realities as guidelines for the organization of life, society, government, and the world itself (Drayton 2000; Harcourt 2011). In other words, the Physiocrats introduced the notion of nature into economy, and in turn, the notion that one could use science to divine the optimal, natural rules for organizing that economy.

The Physiocrats, in short, advocated a belief in a collection of discoverable, fundamental natural laws established by God, which he had established to promote the welfare of mankind; consequently any ‘good government’ or ‘positive law’ introduced by mortal humans could only hope to manifest and guarantee such natural laws, not add to or perfect them. Therefore, according to Quesnay there was no need for a separation of governmental powers; the doctrine of natural order required only a “unified executive” power helmed by a “legal despot” who would merely create a space for and “implement the laws of nature,” and the step back from them (Harcourt 2011, 93). Paradoxically, the philosophy of natural order, according to its very theorists, “inexorably led to a political theory of despotism. Natural order in the autonomous economic sphere demanded, first, that here be no human intervention in terms of positive law in the economic realm, and second, that positive law limit itself to punish the deviant” (Harcourt 2011, 93). In other words, anyone who deviated from the natural rules of economic exchange, as divined, written, introduced, and policed by these elites, threatened the natural economic order with their unnatural behavior and must therefore “be treated as criminals and punished severely” if this divinely-appointed, self-regulating order were to develop and flourish according to its nature. If implemented correctly, Quesnay's economic government would guarantee an end to the booms and busts that created social disorder. There will

> no longer be any scarcity as a scourge … this phenomenon of scarcity, of massive, individual and collective hunger that advances absolutely in step and without discontinuity, as it were, in individuals and in the population in general. Now, there will be no more food shortage at the level of the population. But what does this mean? It means that we succeed in curbing scarcity by a sort of "*laisser-faire*," a certain "freedom of movement (*laisser-passer*)," a sort "[*laisser*]-*aller*," in the sense of "letting things take their course." It means allowing prices to rise where their tendency is to rise. We allow the phenomenon of dearness-scarcity to be produced and develop on such and such a market, on a whole series of markets, and this phenomenon, this reality which we have allowed to develop, will itself entail precisely its own self-curbing and self-regulation. So there will no longer be any scarcity in general, on condition that for a whole series of people, in a whole series of markets, there was some scarcity, some dearness, some difficulty in buying wheat, and consequently some hunger, and it may well be that some people die of hunger after all. But by letting these people die of hunger one will be able to make scarcity a chimera and prevent it occurring in this massive form of the scourge typical of the previous systems. Thus, the scarcity-event is split. The scarcity-scourge disappears, but scarcity that causes the death of individuals not only does not disappear, it must not disappear. (Foucault 2007, 41-42)

Curiously, this innovation produced two fairly opposed economic developments that nevertheless shared a few key thematic and ideological assumptions in common – the Physiocratic approach to a *savant*-divined, but politically-imposed sovereign police order into the economic sphere, ultimately understood as a means for imposing nature's rules in the realm of human governance. The argument for guaranteeing (divine) natural order through economics is an argument explicitly opposed to those that produced the apparently infinitely expanding lists of thoroughly human and terrestrial police ordinances, including the *police des grains*. Quesnay sought to discover the principles of nature and allow them to simply unfold perfectly, allow things to move and flow, create the standards, measurements, information systems that would allow for such flows by putting one market in touch with another, while also permitting the government to see, track, record, and control such activities. Government's role was to guarantee perfect liberty through despotism, to carve out a space of *lassier faire*, and to prevent deviation from that order, punishing those who attempted to circumvent God's plan. Adam Smith, by contrast, would insist on a more active hand in economic affairs, if still an invisible one.

Opposed to this image of a disciplinary state full of burdensome regulations, designed to operate like clockwork was the liberal tradition as introduced most emphatically by Quesnay and taken up and developed by Smith, who was deeply influenced by Quesnay and indeed described himself and his work in terms of police up until his Wealth of Nations. Smith's work suggested that, as opposed to the scientific imposition of a correct and Godly natural order upon market society, the purpose of government was instead to carve out a space in which that natural order could simply be depended to emerge on its own, and produce its own truths and efficiencies.

Smith's criticism of the Physiocrats was based first of all on their misrecognition of agriculture's role in the creation of value; he famously argued that it was not necessary to seek perfect liberty or produce 'legal despots,' but to the contrary, that human 'self-interest' and 'natural desire,' a different and lighter engine of natural order and economic growth, were all that was necessary, and should be allowed to unfold on their own (within the protection and parameters of a well-policed market, that is). In Smith's thought, self-regulating mechanisms replaced these ostensibly 'oppressive' *police des grains* and despots, allowing for free markets – free from regulation, free to operate according to the natural order of human self-interest, and a handful of natural laws like supply and demand etc. – to grow and flourish. This line of thought was taken up and influentially renewed in the 20th century by the cybernetically, informatically influenced Chicago School and Mt. Pèlerin Society and their passionate faith in the naturalness of the market, particularly as the market was perceived using and, ultimately, defined *as* an information machine. In short, the dominant political-economic paradigm of modern liberal capitalism, one that seeks to avoid 'government intervention' in the market – including farming markets – due to the supposed inefficiencies and inaccuracies of such regulatory intervention, is in many ways perhaps best understood an act of transferring the responsibility and authority of regulation and policing of markets from the public to the private. In this model, corporations represent an important regulatory – that is, police – force in markets and particularly in the supply chains that fuel them; the agricultural supply chain is no exception.

In short, the science of police, the *police des grains* never disappeared: "the entire history of the Chicago Board of Trade is, in truth, a story of a strict *police des grains* masquerading under a free market rhetoric (Harcourt 2011, 179). The concept of nature inserted into economy simply masked the state's role, and created a fascinating and bizarre chimera of "liberty" that is, in fact, an endless system of "security;" the very inauguration of the carceral state in the police order of liberal capitalism, a state whose only legitimate role in this account is to police, punish, and ensure every form of security for and around the market *as* society (Polanyi 2001; Harcourt 2011).

i. Code as Law as Police des Grains

In sum, not only is the "government of nature" – whether pursued in the name of king, state, or capital – a very old and established endeavor, contemporary "government" itself can and probably should be understood partly, if intrinsically, in terms of a striving towards an ever-more complete government of nature. Smith (2011) makes interesting and compelling arguments against this characteristic of the modern nation-state as an arrangement of human political power over environments and territories he calls "ecological sovereignty." Agrawal (2006), from a different but related perspective, has studied how the emergence of the environment concept and the sciences of ecology have contributed to a new power/knowledge formation, what he calls "environmentality," that contemporary, sovereign government adopts in certain contexts. Similarly, Drayton (2000) and others have dedicated significant attention to the statist and especially imperial dimensions of what he has called "nature's government," in which the technology of royal and colonial gardens, agricultural improvement initiatives, and similar systems and developments were dedicated to increasing the power, reach, and wealth of imperial European nations through their colonial and commercial networks. While these are fruitful and certainly connected conversations regarding the question of the government of nature, I hope that through the above discussion I have adequately differentiated my concerns and focus on the confluence of the philosophy of government/political œconomy, the informatic/control technologies of police/y (e.g. statistics, metrics, codes, *economics* itself), and their techno-political relationship to a government of things that include the cultural techniques of farming from these otherwise very much related works.

The whole history of European/imperial agricultural rationalization and industrialization, for instance, should be understood at least in part through the lens of endeavors towards a more extensive, reliable, and productive government of nature inhering within a complex web of relations with many more devices and goals. The informaticization and datafication of farming represents a directly related endeavor, developed upon and insinuated with industrial technologies, and refined towards many similar or parallel ends (greater productivity, greater profit margins, greater control, and the moral, ethical, aesthetic, and cultural values that shape and inhere within such purposes).

All that is to say, if "police begets good order," in the words of Peter the Great, it also begets information (quoted in Neocleous 2000, 5). The *Staatsbrille* of police are the lenses of data, the standardization and precision of metrics, they precipitated the "avalanche of printed numbers" (Hacking 1982) and, at every step, the imperatives and contexts, the precursors to and foundations for the rationalized thought-labor factory called a computer. In short, in addition to, and perhaps before and after everything else they are or can be, computers are police/y machines. Computers are police/y machines in as much as they are government machines; and, as Lawrence Lessig has pointed out, both computers and governments run on *code*.

Many scholars in recent decades have made similar observations, some of whom have argued from myriad perspectives that this symmetry is by no means coincidental. One such argument, embraced here, can be indexed as 'historical' in nature, of which Agar's study of the government machine is an admirable example. As he put it, "the state provided a model of organization so fundamental that considerations of 'order,' 'framework,' 'structure,' and 'machine' are inextricably linked with understandings of 'state' or 'government.' This [can] be considered as asserting, in its extreme form, that **to study the history of technology is to study the state, and vice versa**" (2003, 3). I cite this passage to subscribe to it, and would only add that in the era of the market society, when the historical analysis of *political œconomy* and natural order outlined above is followed to its logical conclusion the state can also be profitably understood as the apparatus of/for implementing the market, and the organization of nature-cultures it requires. This is even more the case when considered in the light of the reigning theory of the market as an informatic truth machine, natural and efficient; here the state-machine and its administrative media are the hidden thing that makes the market look natural. In other words, the study of the state is also the study of the market as technology, state/market are fundamentally connected, even when the market is 'private' and 'free'.

Another major thread of argumentation regarding the relationship of code to law stems from what for simplicity's sake I will call a Kittlerian perspective on computing media. Vismann (1999) is emblematic of this approach, arguing that the conditions of possibility for the practice and execution of law are the symbolic, information media apparatuses that allow these to exist in the first place. "All legal acts," Vismann writes, "operate on an administrative basis," because law "is a form of putting in order, arranging, assigning, categorizing, data-processing. In other words, jurisprudence as a science of transfer concretizes its juridical apparatus of knowledge as an administrative machine" (1999, 284). Consequently, law as code, as a symbolic technology, is inseparable from the technologies and literal machinery that make it possible (books, shelves, paper, archives, computers, mail, storage media, office buildings, secretarial techniques, etc.).

Yet Vismann elsewhere is at pains to emphasize that following the advent of the computer, which was technologically conceptualized and constructed in a way that resembles the very governmental architectures it is designed to assist – it "behaves in a lawlike manner" and "functions according to a juridical logic" as she puts it – marked the a recursive moment in which the computer began to "[impose] its logic on the law," and vice versa (2007, 91, 93). Moreover, the advent of the personal computer in the 1970s, which marked the beginning of a change in the nature of most computer operators from programmer to user, meant that the operator as user was "no longer confronted with the entire machine and its outlandish code;" from this point on the "machine appears to 'speak' the user's language; the personal computer seems merely to execute the user's will," through the use of higher-level programming languages (source code) and pre-programmed software packages (2007, 95). This organization of technology and technique has led to a prominent tradition in which the computer user is figured as a kind of sovereign in miniature, an executive in charge of an entire digital administrative apparatus, a literalized Agar-ian digital 'civil servant' that exists to 'im-mediately' (so to speak) execute their will with absolute obedience, everywhere and everywhere, despite in fact interpolating that user through the concretization of pre-existing programming choices a given system presents them with.

Galloway (2004) develops this line of thinking about computers as a kind of pure executive technology, a wizardlike spoken spell, in a particularly striking way. Following from Friedrich Kittler's assertion that "there exists no word in any ordinary language which does what it says," that "no description of a machine sets the machine into motion," Galloway argues that digital code, by contrast, "is the first language that actually does what it says—it is a machine for converting meaning into action (2004, 166)." "Code is a language," he concludes, "but a very special kind of language. Code is the only language that is executable" (2004, 165-66). Such a conclusion represents something of an apotheosis of this line of thinking about the implication of the ways in which code, laws, and rules are imbricated in the figure of a digital police/y machine, a government in miniature at the command of a petit sovereign. This is, in short, *precisely* the imaginary of digitization at the heart of the informatic ideal of precision agriculture, a dream of the mediation, control, and consequently perfect government of nature made possible by and through the police technology *par excellance*, the information machine. This dream is expressed in liberatory language to be sure. The opportunities opened by these great progressive achievements are opportunities to improve the world (in every sense of that word) through greater efficiencies that, happily – but not necessarily deliberately – result in world-sparing environmental benefits. A future in which every agent of the agri-food system is become a small digital sovereign, "sourcerer" of their own miniature fiefdom, is a future of endless value adds for the market and nature in equal measure.

To his credit, Lessig (2006) advances a more limited, historically-grounded, and specific series of claims with his superficially similar assertion, following William Mitchell and Joel Reidenberg, that "code is law." Lessig argues that computer code is a new kind of regulator that *adds* to other types of regulations like laws and norms, expanding the space of regulation in two directions: inwardly, into the computer and "cyberspace"[29] where it *literally* operates as law, and outwardly, where computers running code as [internal] law operate in and upon the world as a *medium* for its "lawmakers" – programmers – without simply serving as a purely executable language determining reality itself in a Kittlerian mode. "If code is law," Lessig argues, "control of code is power;" consequently, that power must be taken seriously and subject to debate if it is not simply to exist as a privatized "architecture of control" designed by and for private interests. "Architecture is a kind of law," he contends: "It determines what people can and cannot do. When commercial interests determine the architecture, they create a kind of privatized law" (77). In a distinctly Mouffe-ian or Rancière-ian mode, Lessig insists that the regulatory applications and effects of computer code should be "decided by argument, not definition," (2006, 324) insisting on a kind of digital "agonism" that would be endorsed by Crawford a decade later (2016).

Chun (2011) picks up the argument Lessig advances in a particularly compelling way, explicitly useful for developing these theories in relation to the digitization of agriculture. Chun follows a thread from earlier work (2008) in which she defines the discourse of user as sovereign – exemplified by Galloway and Kittler's assertions – via the mediation of the user's will through anthropomorphized, high-level "source" code (e.g., the notion of the user as the "source" of agency/power) as a kind of "sourcery" that rests on a flawed conception of the nature of code and computer operations. Chun contends that such arguments foregrounding the role of source code ironically "anthropomorphize the machine and reduce all machinic actions to the commands that supposedly drive them" (2011, 101). In the seemingly endless accounts of coding, digitization, smartification, computerization-as-savior, what stands out is a contextual

[29] The 1st edition was written in the 90s, give him a Gibsonian pass.

imaginary such visions inhere within, one which dreams of code as agent and user as petty (and given the discussion above, intrinsically patriarchal) sovereign, and in which the fabric of reality is understood through and as *logos* to the exclusion of all else.[30] In such Austinian discourses and dreams of the digital "code is – has been made to be – executable, and [this] executability makes code not law but rather every lawyer's dream of what law should be: automatically enabling and disabling certain actions and functioning at the level of everyday practice. *Code as law is code as police*" (Chun 2011, 101; italics mine). "Not accidentally," she continues, "programming in a higher-level language has been compared to entering a magical world - a world of logos, in which one's code faithfully represents one's intentions, albeit through its blind repetition rather than its 'living' status" (Chun 2011, 101-102).

This argument goes some way towards grounding the puerile and bathetic rhetoric that riddles Silicon Valley accounts of digital technology as "magical" and "revolutionary" in the patriarchal, historically white supremacist imaginary of an imperial Western noble elite. Code as law as police is a discourse of reassuring (normative) power, presenting an image of a sovereign whose desires and commands are perfectly embodied and immediately executed. In other words, this is an imperial dream of perfect government under the control of a legal despot – whether that despot is a farmer-owner, a corporate executive, or an EPA employee is just a question of who's doing the dreaming. There is a reason cybernetics and computers (police/y machines) have been perceived as viable by anticommunist Cold Warriors and socialist revolutionaries alike (Medina 2011; Peters 2016); cybernetics (*κυβερνήτης / kybernitis) is first and foremost a government*

[30] Here I would add/argue that *logos* in this sense is precisely *information* in the Wiener-Shannon tradition. Chun in other words is outlining a critique of the discourse of informatic ontology which serves as the condition of possibility for seeing code in the way she describes.

(κυβερνᾶν / kybernan) technology, instantiated qua *government machines, as a technological apparatus for assisting in achieving and maintaining government.*

Sourcery is/as fetishism of police; *code as law as police* is the fable of code as laws that finally ‘do exactly what they say,’ producing perfectly controlled spaces, architectures, actions, phenomena. It is a discourse of the end of politics, a dream of pure consensus, run on code. To the contrary, computers, like any technology, are an embodiment of and site for social relationships; police and politics. The digitization of spaces and activities, environments and farms included, certainly has very real effects and produces change. It may be that the best way to understand such changes is not through the dystopian picture of the final and perfect (totalitarian) ordination of capitalist nature, victorious everywhere forevermore, but in the way that digital technologies tend to bring their information-technological kin – bureaucracies, of both state and capital – closer and more present, in more ways, to the objects they regulate. In that way, they tighten the police-policy relationship, extend it, make it more possible to manifest it or activate it in more places, because of the automation and speed that computers afford the bureaucratic information management apparatuses they are used by, whether ‘public’ or ‘private.’ In short, such dreams of a modern government of nature, designed to rescue the world from the brink of ecological catastrophe through its application to farming in the guise of *precision* or *digital agriculture*, represent a revenant, contemporary dream of *code as law as police de grains*.

But as Harcourt among scores of others have shown, such phenomena ultimately depend on a more fundamental police violence exercised by the state – an edifice more or less reduced to legitimately performing that function in influential American liberal ideologies – in order to shore up the un/free market system by controlling and disciplining those who do not conform to it or seek to exploit, escape, or undermine it. Such a promise or dream of *code as law as police des grains* as has unfolded *qua* the socio-technical system of *precision agriculture* is particularly concerning, as it takes its technological, political, socio-economic, and epistemological conditions as ahistorical assumptions which it at once not only leaves intact, but seeks to shore up, strengthen, and maintain all the while suggesting it represents the advent of a bright, orderly, revolutionary future.

Police and policy, therefore, are not only one in the same etymologically, they are in effect, as well. These technologies developed ultimately in distinct ways, but both remain aimed at the production of specific organizations of reality, of implementing and reproducing specific, subjective, perspectival social constructions of order.

This is why code is law is police in a literal sense on one hand – this phrase is naming, literally, a spectrum of technologies aimed at effecting the same thing (an order) in this historical/social context (liberal democratic capitalism). What an account of the symmetry of the digital and the governmental in, for instance, Vismann's case lacks is a historical and political analysis of the state form that is mirrored in code. Code as law as police helps to highlight a desire to effect, algorithmically, automatically, mechanically, specific orders, to disallow and allow certain behaviors, access, actions, perspectives; to, wherever possible, short circuit and expand the police enforcement of policy with the policy enforcement of policy, e.g. code. To pre-empt the need for police with code-as-law-as-police. Embedding code into the architectures, infrastructures, and environments as in the dream of an internet of things, 'pervasive/ubiquitous' computing, smart cities etc. represents an act aimed at policing those spaces towards specific ends & orders, generally 1. in the name of keeping the "natural order" of the market operating, and relatedly 2. In the name of keeping the social order beneficial to the owner/ruler classes predicated on the previous item in place

Precision agriculture understood through the lens of code as law as *police des grains* therefore does not represent the *actual* achievement of a pure and complete mastery of nature in the name of bending it to an order it seeks to sustain – this is the meaning of sustainability, the cybernetic refusal of the future in the name of homeostasis, the reproduction of the present distribution of the sensible – although this is precisely the dream/achievement such an approach embodies.

The informatic ideal in farming is that which collapses revolution into sustainability (of the present order). In this sense the precision revolution is exactly an act of police, the maintenance of a given distribution of the sensible that is achieved with police/information technologies, "government machines" designed explicitly to keep a given order in place, in good order. It is literal revolution insofar as it represents changes dedicated to remaining the same, change in order to sustain the present. There will be no 3rd or 4th "revolutions" unless by revolution we mean a kind of movement designed to sustain a given position/distribution of the sensible. The sensible, literally and figuratively, here is capitalism and the liberal state. This partition of the perceptible, of the valid, recognized, communicable, commensurate, normative hetero white supremacist capitalist realism, will remain a non-revolutionary revolution so long as it continues to refuse to take account of the speech of the plenitude of others, to stop dismissing the expressions of flora and fauna as merely indications – indications to be registered, yes, but not ac-counted, to be recorded as data that permit a more effective police of the extant – until humans stop treating these things as noise instead of speech, having no part in this partition or party, no simple change in techne can possibly mean something truly revolutionary, which is to say, political.

Precision agriculture in many significant ways advances an imaginary of code as law as *police des grains*, a *police des grains* that never actually left us for the soothing touch of an invisible hand, but continues to masquerade under a "free market rhetoric," particularly but by no means exclusively visible in the case of precision agriculture a rhetoric of 'transparency and traceability' (Harcourt 2011, 179). In presenting precision agriculture this way, I am arguing that as it exists at present, it represents a kind of return of the Physiocratic dream of a police-enforced natural order born anew as an informatic ideal; as though if only we could identify, register, record anticipate, and control everything we could bring our economy, state, society into accord with nature itself, perfectly, a true reign of the sustainable / sustainable reign. Such a perspective is reflected in the criticism Jacques Rancière (1999, 2010) raises of the project of political philosophy which seeks a final and ultimate principle of *arkhé*, to finally achieve the perfect police/policy that covers everything, integrates everything, works, machine like, frictionlessly, without conflict. Instead, to conclude this study I would like to ask what would it mean to relinquish such a dream, when the problems and questions of modern agriculture, and the capitalo-polis that propels it, are not necessarily those of life or death due to lack, but due to hyperabundance violently extracted, unequally accumulated, and unequally shared?

PA is an intensification of conventional agriculture presented as a radical break. The realities of its use in many instances contradict this controlled, efficiency-generating, environment-sparing public image. An "unrelenting abundance" (CoBank 2017) of agricultural *overproduction,* crashing prices and driving farm consolidation, contradicts the major rhetorical framework of PA as answering the call for "100% more" food by 2050 (Grose 2015). To be meaningful, such calls must be placed within the broader context of current production and distribution systems, which waste up to 40% of the food produced in the United States (De Schutter 2015). Issues of hunger, nutrition, and culture normally corralled under the mantle of “food security” are not issues of simple scarcity; they are in large part socially, politically, and culturally-shaped issues of distribution—both of food itself, and of power more generally (Gunders 2012; Graddy-Lovelace 2017). Questions about production and waste are also questions of cultural norms, particularly those which tether authenticity, masculinity, vitality and wealth to the slaughter and consumption of other species. The overwhelming majority of cultivated land in the U.S. is dedicated to the manufacture of singular commodity crops, the vast majority of which are not grown for direct human consumption. Monocrop agriculture is profoundly tied to the production of livestock, primarily cattle; millions more acres are invested in the production of biofuels (Merrill and Leatherby 2018). As agro-ecology and food-sovereignty movements have highlighted, conventional capitalist agriculture has at best a tenuous relationship to the dynamic needs and desires of people and other biotic communities around the world (Frison 2016).

PA’s environmental benefits are also presented in terms of greater monocropping intensity—more food can be harvested from the same land while sparing inputs. Yet more granular analysis of these issues suggests no easy answers. There is no final verdict, for instance, on whether “land sharing”— attempts to make farmland more hospitable to local fauna by adapting it more holistically to the surrounding environment, and so reducing the harm of further expansion—or “land sparing”— attempts to maintain or reduce cultivated areas overall by pursuing yield intensification—is clearly superior (Ericksen 2009; Balmford et al. 2012, 2716-17). A recent and deeply worrying review of over 70 conservation studies has shown that 40% of insect species on Earth are experiencing “dramatic rates of decline” (Sánchez-Bayoa and Wyckhuys 2019, 9). The authors explicitly identify conventional agriculture, and the shift from low-input to “intensive, industrial scale production brought about by the Green Revolution” as a core driver of these trends, where planting genetically uniform monocultures, using synthetic chemical inputs, fencerow-to-fencerow planting eliminating not only forests but individual trees and hedgerows and large-scale irrigation effectively create engineered deserts, hostile to anything but single, commodified species (Ibid., 19). Birds, fish, mammals and reptiles have fared equally poorly, with 60% of their total populations having declined since 1970, industrialized farming again a major driver (World Wildlife Federation 2018).

Consider the following: in July 2018, I was invited to interview a Western New York farmer on his use of PA as he harvested a neighbor’s wheat. While we drove, his combine would pass over dells and furrows of deep green. As I watched the occasional congress of weeds appear on the combine’s digital display, recent environmentally-oriented arguments presented at an international PA conference were brought to mind: that datafication could identify unprofitable areas to take out of rotation, helping reduce harmful agricultural effects. I asked my companion what he thought about these patches:

> **Q:** When … you’ve got more topographical issues like that, would you consider rearranging your field so you leave some areas fallow?
>
> **A:** Oh, absolutely. If there's no way to make it economically viable, you're better off to not work that. Absolutely. And that's where the precision [technologies]—they'll just put a dollar amount to that spot … Now the farmer in me might have to, I see that spot right there, and what can I do to make that grow? And I'm going to figure it out. <laughs>. Usually there's an issue that can be fixed. And so I'll just use that as an example. There's a drainage issue right there. I know there's a drainage issue right there. And how can I fix that? Well, we put drainage tile in, and we can fix that spot … I could make that spot more consistent with the rest of the field.
>
> **Q:** So … the equipment helps you to identify those areas to say ‘okay, well, it might make more sense for us to spend the money to put the tile in to make that more viable for us?’
>
> **A:** Yes, versus leaving it fallow.

This exchange exactly reproduced the arc of conversations at the conference panels. While everyone initially agreed precision environmentalism was a nice thought, and that NDVI images or yield and profitability maps helped identify ‘problem’ areas, many were quick to ask why a farmer wouldn’t rather simply treat those areas, making them profitable rather than removing them from rotation. One would lose money not harvesting such areas—something the New York farmer was quick to point out as well.

Who can blame him? In a capitalist monocropping system, it makes far more economic sense to keep an entire field uniform than to drive a huge combine harvester around several four-foot-square patches. The problem is not so much that an individual farmer fails to be environmentalist enough; the problem is with a conventional system whose underlying logic and imperatives inevitably make a market-based choice more viable than an ecologically-informed one.

There are of course many other problems raised by the prospect of maintaining the conventional, capitalist food system, from digitization as a driver of consolidation and the stresses this process places on rural communities, to its contribution to waxing power of grocery store chains and food manufacturers over the labor and environmental conditions farmers and farm workers work within. Yet it would be folly to suggest that this system, on its own terms, has not been successful in a very strict sense. The increase in yields, and so overall availability of food represented by the hybridization of corn and later “Green Revolution” technologies cannot be denied. But these increases are predicated on a process of externalization that can no longer be supported; the historically limited “cheapness” of labor, environment, etc. have been all but burned through (Moore 2017). As the UN itself has recently recognized, capitalism as such simply cannot continue (Järvensivu et al. 2018). Neither, therefore, can conventional agriculture, precise or not. The question is, what will replace it?

While it is decidedly outside the scope of this thesis to answer that question in full, within the more limited scope of agriculture, I see promise for rethinking the use of PA technology along the lines of what Kate Crawford has called a design ideal of "agonistic pluralism" (2016). Unlike the functionalist rationality of digital systems which enact universalizing, black-boxed logics of productivity towards police and control over the production of surplus value, agonistic perspectives are premised upon an "ongoing struggle between different groups and structures—recognizing that complex, shifting negotiations are occurring between people, algorithms, and institutions, always acting in relation to each other" (Crawford 2016, 82-83). Precision agriculture shifts the scale of attention and intervention from field-level to sub-field control, but it does not question the monocrop, factory-field itself, the literal and figurative ground it is built upon.

Yet there is no *inherent* reason that sensor and processing technologies, which permit more finely grained interventions in food production, could not be designed to facilitate greater ecological complexity without compromising productivity. If, at present, machine learning is designed around a commodity logic towards more efficient maintenance of the conditions of production, i.e. through neural networks designed to automatically recognize and eliminate "weeds" and other pests, agonism in this context could mean finding ways to allow for *greater* floral and faunal complexity around fields, using robotics, automation, and algorithmic machine learning to negotiate the conflicts in a multi-species ecological milieu (cf. Tsing 2015). The tools of military-industrial "precision," that is, can and should be rethought to encourage, not eliminate, the thronging complexity of being, and so help shape our *techne* in better accord to both the real needs of people, and other forms of life. Toward this end, I believe the definition and conception of *politics* and *police* that Rancière has advanced (1999; 2010) is useful for framing the question of what such an approach might look like, what kind of intellectual or ethical basis it might be grounded upon.

In short, I am here advocating against a design philosophy that seeks to perpetuate the police dream of an infinite extant – the sustain-ance of the existing distribution of the sensible, the existing allocation of validity, legitimacy, intelligibility, responsibility – through greater exertion of police technology designed to refuse the future through more exquisite and universal command, control, and government of the present. To the contrary, I advocate for an aesthetic, technological, and ethical philosophy that follows the genuinely political call, in Rancière's sense of the political, to recognize the voices of others *as such*, and in so doing, incorporate them as part of the perceptible, a recognition of community that transforms the 'lowing of animals' – as well as the comm/union/itas of plants, fungi, et al – into something intelligible, into *speech*. A key interest in any future work that departs from that presented in this study is to develop alternative understandings of 'control' and 'culture' that follow from the act of and orientation to a politics of biological democracy and political equality, one that follows an an- *Arkhé*; against the efforts to assimilate everything to a perfect political principle, an ideal, optimal, precise, perfect, sustainable order; to deny the existence of the/any wrong, to eliminate the wrong from the sphere of the just and right, of the law, the order, the police of being.

The distribution of the sensors in precision agriculture determines the distribution of the sensible in conventional farming. Simply extending this distribution incorporates the existing parts and partitions of culture, race, gender, ability, species, into that police order, it does not challenge them. It incorporates them to better ac-count for and control (*contra-rolle*) them. In contrast, I am interested in the capacity or ability to not incorporate; engaging in the mediation of nature and the development of new *kulturtechnicken* in order to more carefully and thoroughly learn the speech of things as an act of politics and admission of ontological equality, i.e. in order to better *not* incorporate other species into some system or principle of ecological government in the police name of normative human exceptionalism and market relations. I would like in future work to develop an alternative conception of control, a kind of control as *decontrol*. In contrast to control as a reaching out, grabbing, holding, possessing, ordering, managing, dominating, seeing and knowing like a predator, *incorporating* (to an *arkhe*), I am interested in exploring control as a restraint, as self-control, as accountability, responsibility, caution, an ability to stop, to hold-off, to *release*, to *let go* (of/from an *arkhe*, to be an-*arkheic*). Control as account*ability* [to a democracy of being] rather than accounting. Not a manifestation of anarchic "chaos" *qua* entropy, but an equality as the absence of hierarchy that requires relinquishing certain police principles of rightness, deservedness, justification intrinsic to the conventional Western, capitalist, patriarchal, imperial organization of agricultural production and its intensification through the introduction of an informatic ideal of digital precision, the advent of the data farm and the dream of a government of nature it contains.

CONCLUSION

This dissertation has presented a critical, historical, empirically-grounded analysis of precision agriculture. It has argued that contrary to the truth claims and dominant rhetoric organizing precision agriculture a practice, an industry, a discourse – claims that precision agriculture represents a revolutionary, disruptive step towards a 3rd green and 4th industrial revolution that will usher in a future of greater efficiencies, less work, and environmental salvation – precision agriculture represents efforts to protect, shore up, maintain, and intensify the conventional industrial agri-food system of capitalist monocropping agriculture.

A better way to understand precision agriculture, I contend, is in terms of the introduction of an "informatic ideal" in farming, one rooted in an earlier industrial ideal, but that in addition to its continuities with that earlier history represents an extension, intensification, attention, or replacement of that ideal in various respects. Precision agriculture as an existing apparatus is the name of a system designed to interpolate the earth, to instantiate the factory-form necessary to respond to the imperatives of capitalism all the more effectively and extensively. At the heart of the informatic ideal so-defined is a dream of control, a mediation and government of nature that represents in turn a more effective government of people, one achieved by code as law as police des grains. Yet real change *must* come, for abundantly clear ethical, political, and environmental-ecological reasons. I suggest that this change might be imagined using the framework of police/politics Rancière advanced as a principle for design and development that would offer *genuinely* revolutionary technologies and meaningful social and environmental benefits.

This project was conceived in early 2016, at a time when there was effectively no critical research or literature on precision agriculture as a specific socio-technical phenomenon. It was conceived specifically to address that lack in general by offering a critical account that would engage with the discourses and technologies of precision agriculture, demonstrating its historical roots and political qualities in an environment of techno-futurism and technological determinism that began from the premise that neither existed. Since that time, scholars in Science and Technology Studies, Sociology, Geography, and related disciplines have begun to attend explicitly and deliberately to the manifold specificities of precision agriculture as a system and phenomenon. Modified parts of this work have been published, or are under review, as contributions to that body of scholarship and burgeoning literature. Out of the more general context of this project's conception, in these pieces I have offered more narrowly focused arguments about the role of precision agriculture as a normative force in farming, and an argument/call for an explicit and deliberate media studies of agriculture given precision agriculture's role in accelerating and expanding the mediation of rural and environmental spaces and non-human worlds.

Given this project's contextual conception and the time it has taken to bring it to fruition, several limits in its scope and results have presented themselves. First, while a general critical framework for precision agriculture remains valuable, and I believe in this study I have contributed new knowledge and advanced the academic fields to which I belong by developing and presenting useful findings and concepts, particularly those of the "informatic ideal" and the "government of nature" as a form of digital police/y, my research reveled this subject's massive complexity, a complexity this project has not done justice to. A narrower focus on a more specific practice, technology, or concept would have presented both a simpler project and a potentially tighter, more practical, tangible body of scholarship. Serious and dedicated research is needed on the development of dataveillance on the farm, of workers, of flora and fauna, and of farmer-owners themselves. Questions I was interested in addressing at the outset of this study regarding differential uptakes of precision agriculture technology in different practical, climatological, topographical, and cultural contexts had to be set aside, but remain real and fruitful areas of study. Similarly, a substantial portion of planned research on the role of information technologies, particularly those for the organization and administration of colonial territory, in producing specific conditions of possibility for the usefulness of precision agriculture as a series of techniques and collection of technologies had to be cut for practical reasons. The reality is my research raised more questions than produced insights or answers, and highlighted more shortcomings and limitations than I was able to meaningfully address.

I see these latter questions, concerns, and problems as useful for directing my future research in this area. This research project has provided me with an education in several fields, particularly the histories of agriculture, police, capitalism, and certain influential theories of media, that I previously lacked. Taken together, this thesis has resulted in the training of a graduate student in both a type of project and intellectual field that has prepared him for a pending postdoctoral research project in and through which he can address some of these shortcomings, as well as test and implement findings and tools developed through the course of this research. Beyond its impact on this more immediate project, I see significant potential for the development of elements of this work into a dedicated scholarly monograph. I am interested in pursuing further work in developing a media studies of agriculture, as well as refining, reinforcing, and improving my treatment of the questions of government in farming – both in the historical discussion of police and computing, and in the contemporary phenomenon of supply chain governance in the form of transparency and traceability initiatives. Finally, I am particularly interested in further developing the concepts and discussion at the very end of this study concerning a foundation for alternative uses and designs for and of precision agriculture technology along lines that take the democratic politics of equality seriously. I can see no hope in a future of agriculture that dreams only of squeezing ever-diminishing returns out of increasingly policed life and land; only ruin, blood, heartbreak, and brutal constraint as the social, political, economic, and environmental processes we are already seeing unfold at the behest of capitalism's epochal tenure accelerate. If this future is to be foreclosed, genuinely new ways of thinking and doing agriculture have to be practically achieved. I am excited by the prospect of helping to contribute to those efforts, and this project represents a first step in that direction.

Appendix A – Research Methods

I. Research Overview

a. Research Timeline

I undertook this project from 2016 to 2021. Conceptual work began in 2016; in April 2017 I successfully defended my prospectus and began primary research and writing. I completed primary work on the project in December 2021, and successfully defended this thesis on the 9th of that month.

b. Internal Review Board

This project received Expedited approval from the Indiana University Internal Review Board on April 3, 2017, and was designated IRB Study #1703557717. It was determined to be of minimal risk, and documentation of informed consent was waived per 45 CFR46.117(c). This IRB protocol was closed in November 2021.

c. Funding

This project received financial support from the following sources:

- **2018** – Doctoral Dissertation Research Improvement Grant, National Science Foundation, Award #1755078. ($9,248)
    - College of Arts and Sciences Dissertation Completion Fellowship, Indiana University. ($25,000)
- **2017** – College Arts and Humanities Institute, Graduate Research Travel Award, Indiana University. ($800)
- **2016** – Rob Kling Center for Social Informatics Student Research Grant, Indiana University. ($1500)

II. Methodology

This study employed two basic methodological approaches:

1. **Ethnographic** – semi-structured and unstructured interviews, participant observation, and creation/collection of audio and visual media.

2. **Critical** – critical discourse analysis, literature review, and historical and historiographic research.

1. Ethnographic

a. Interviews

From 2017 to 2019 I conducted formal, semi-structured interviews with 21 informants in the Northeastern, Midwestern, and Great Plains regions of the United States. My interview subjects included farmers in each of these regions, as well as agricultural researchers in university (faculty, postdoctoral fellows, and graduate students) and government positions (chiefly USDA Agricultural Extension/Experiment Station employees), equipment manufacturers, retailers, and service providers, and others in some way employed in or working in relation to the agri-food system in the United States.

Of note to the conclusions and limitations of this study, of the farmers I spoke with, all were farmer-owners or members of the farm staff engaged in conventional, production-oriented agricultural practices. The vast majority of these owned or operated very large farms (measuring from the thousands to the tens of thousands of acres in size), and all had adopted some form of precision agriculture technology or technique. In my attempts to recruit informants for this study, I was consistently put in contact with farmers of this type, seemingly owing to 1. Intermediary's perceptions that I would want to speak to adopters, and 2. Referrals from one interlocutor to another often meant I was speaking to social peers, running similar operations. While over the course of this study I was in regular contact with small-scale farmers of various types and using various approaches, I did not have the opportunity to conduct interviews with them.

Consequently, this study is significantly limited in its data collection to large farms with various degrees of precision agriculture adoption.

Similarly, I was unsuccessful in my attempts to recruit farm workers to this study. This was in part a result of heightened concerns around the activities of ICE during the years 2016-2020 during which the majority of my fieldwork took place, 2. Ongoing unionization efforts in New York State during this period which similarly made workers understandably wary of participation in such a study, and 3. Unwillingness of farmers to put me in contact with their employees or hired hands. These limitations highlight areas for potential amendment or development in future work on this project.

b. Participant Observation

I performed 7 on-site observations at official events over the course of this study:

- **March 2018** – The Purdue DigitalAg Forum, West Lafayette IN
- **April 2018** – The Machine Learning: Farm-To-Table Workshop at the University of Illinois, Urbana IL
    - Bloomington Food and Farms Coalition Community Assembly
    - Bloomington Farming AI exploratory meetings
- **June 2018** – The 14th International Conference of Precision Agriculture, Montreal, Quebec, Canada
- **November 2018** – The National Conference for Food and Agribusiness, West Lafayette IN
- **May 2020** –Advancing Digital Agriculture and Conservation Policy Workshop, Virtual

I performed on-site observations at 10 of the farms, businesses, and offices I visited for in-person interviews.

At each of these events and field sites I recorded notes and took photographs. I attended scores of individual presentations on business, academic research, and other topics, and at these events engaged in conversations with an unrecorded number of individuals (I estimate more than 50, less than 100) that also were significant to this study's findings.

2. Critical

a. Discourse Analysis

Critical Discourse Analysis represented a major methodological approach undertaken for this study. As noted in the introduction, I performed this analysis on information gathered from literature and historiographic reviews, participant observation, and interviews. I define critical and discursive analysis as an approach to information emphasizing the positioned, historical dimensions of its creation, viewing information and meaning as constantly evolving products of contestation and difference within social and cultural practice (Cf. Foucault 1972; Williams 1977, 1983). This approach is epistemologically focused, and involves political and ontological dimensions of analysis. I analyzed the materials outlined above in order to locate and develop their epistemological patterns or commitments, considering questions including 1.) What are framed as facts, truths, or common sense regarding precision agriculture? 2.) When and where do these appear? 3.) How do these discursive features change or endure across the communities concerned, including farmers, businesses, governments, and the broader public?

b. Historical Research

The chief historical method of this study was historiographic, and involved extensive reviews of literatures on agriculture, digital technology, media, cybernetics, government, police, colonialism, ecology/environment, and technical literature on precision agriculture itself. Additionally I undertook historical research on primary documents, largely through access via the Wells and Lilly Libraries at Indiana University-Bloomington, and through digital portals such as ProQuest, HaithiTrust, and Archive.org, chiefly for Chapter 1's discussion of *broadcast.* I also performed very limited archival research at the Onondaga Historical Association's archive in Syracuse NY, and the Wells Library at Indiana University. This archival research was undertaken for planned sections of this study on colonial technologies of mapping and land organization that were ultimately cut.

III. Data Management Policy

a. Data Formats and Distribution

With few exceptions, data is stored in the following formats: Word, Excel, JPEG, TIFF, PDF, mp3, mp4, and paper. Data will be made available in the form of academic publications and manuscripts filed with IUScholarWorks, as outlined below. Due to the sensitive nature of this data and the need to protect participant confidentiality, interview subjects are anonymously identified in this study, unless they are public officials or have requested otherwise. Interview transcripts and recordings will not be shared in accordance with university IRB regulations.

b. Data Archiving and Preservation

To increase access to the published research that has been funded, listed below, I will deposit this manuscript in the IUScholarWorks institutional repository

IV. Presentation of Results

Results from this study were presented at the following venues:

- **2017** – "The Shape of Food to Come: On Drones, the Mediation of Nature, and Data Farming," Sensor Publics, Technische Universität München, Munich, Germany, April 5-7.

  - “As Below, So Above: Media Farms, Agriculture Drones, and the Quest for Transparent Nature” Society for Cinema and Media Studies, Chicago, IL March 22-26.
  - Organizer and Chair, “Transparency and Opacity” panel, Society for Cinema and Media Studies, Chicago, IL March 22-26.

  - 2016 – “Data Farm: Drones, Ecology and the Future of Food” midweSTS workshop, Chicago, IL September 16-17.

- **2018** – “Technology, Control, Farming” invited talk, Abode Farm, New Lebanon, NY September 9.
  - “Data Farm: On Precision Agriculture and the Political Ecology of Disruption.” XIX ISA World Congress of Sociology, Toronto, ON July 15-21.

- **2020** – “From Enclosure of the Commons to Enclosure of the Æther: historicizing precision agriculture in the birth of ‘the’ media,” Society for Cinema and Media Studies, March 20.
  - Co-organizer, “Farm Tech as Media Culture: The Agrarian Roots of Media Studies” panel, Society for Cinema and Media Studies, March 20.

V. Related Publications

Research results from this study have been published in the following venues:

Miles, Christopher. 2019. “‘The Combine Will Tell the Truth:’ On Precision Agriculture and Algorithmic Rationality.” *Big Data & Society*. https://doi.org/10.1177%2F2053951719849444.

Miles, Christopher. 2021. “Agricultural Techniques: Broadcast, Precision, and the Media of Culture.” *New Media & Society*. Under Review.

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Wolf, Steven A., and Peter Nowak. 1999. "Institutional Failure in Agro-Environmental Management." *Research in Social Problems and Public Policy* 7: 213-310.

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CURRICULUM VITAE

CHRISTOPHER JOSEPH MILES
chrimile@indiana.edu

EDUCATION

Indiana University
PhD, double major: Communication and Culture; Informatics (Computing, Culture, and Society), 2012-2021.
Thesis title: *Data Farm: Precision Agriculture and the Government of Nature*
Co-advisors: Dr. Eden Medina and Dr. Theodore Striphas.

New York University
Master of Arts, Cinema Studies, 2009.

SUNY Oswego
Bachelor of Arts, dual major: History; Broadcasting and Mass Communication, 2005.

PUBLICATIONS

2021 Christopher Miles. "Agricultural Techniques: *Broadcast*, *Precision*, and the Media of Culture." *New Media & Society*. Under Review.

2019 Christopher Miles. "'The Combine Will Tell the Truth:' On Precision Agriculture and Algorithmic Rationality." *Big Data & Society*. https://doi.org/10.1177%2F2053951719849444.

2016 Christopher Miles. Review of *The Cybernetics Moment: or Why We Call Our Age the Information Age* by Ronald R. Kline. *ICON: Journal of the International Committee for the History of Technology* 22. 146-148.

2015 Christopher Miles and Nancy Smith. "What Grows in Silicon Valley? The Emerging Ideology of Food Technology." In *The Ecopolitics of Consumption: The Food Trade*, ed. H. Louise Davis, Karyn Pilgrim and Madhudaya Sinha. Lanham: Lexington Books.

FELLOWSHIPS, GRANTS, AND AWARDS

2018 - 2019 Doctoral Dissertation Research Improvement Grant, National Science Foundation, Award #1755078. Grant awarded in support of research expenses for dissertations in the area of Science, Technology, and Society. ($9,248)

College of Arts and Sciences Dissertation Completion Fellowship, Indiana University. Fellowship stipend awarded in recognition of past achievements and future scholarly merit to support dissertation writing and research in its final year. ($25,000)

2017 College Arts and Humanities Institute, Graduate Research Travel Award, Indiana University. ($800)

2016 - 2017 College of Arts and Sciences Graduate Recruitment Fellowship, Indiana University. Yearlong fellowship awarded for writing and research towards the advancement of my dissertation. ($18,000)

2016 Rob Kling Center for Social Informatics Student Research Grant, Indiana University. Competitive campus award given to a doctoral student studying the ways computerization, the Internet, or digital media interact with people, organizations, or society. ($1500)

2015 Virginia Gunderson Award, for "Digital Accessories: On Access as Apparatus," Communication and Culture, Indiana University. Highest departmental honor; faculty-nominated award for top student paper that year. ($1000)

2013 Brantlinger-Naremore Prize 2nd place, for "FILIAVIATION: On the Cultural and Technological Evolution of 'Drones,'" Cultural Studies program, Indiana University. An award for the best graduate essay in Cultural Studies. ($300)

PRESENTATIONS

2021 "From Enclosure of the Commons to Enclosure of the Æther: historicizing *precision agriculture* in the birth of 'the' media," Society for Cinema and Media Studies, March 20.

Co-organizer, "Farm Tech as Media Culture: The Agrarian Roots of Media Studies" panel, Society for Cinema and Media Studies, March 20.

2018 "Technology, Control, Farming" invited talk, Abode Farm, New Lebanon, NY September 9.

"Data Farm: On Precision Agriculture and the Political Ecology of Disruption." XIX ISA World Congress of Sociology, Toronto, ON July 15-21.

2017 “Democracy Must Be Made Safe for Computing: On the Cultural Origins of Computer Security.” Society for the History of Technology. Philadelphia, PA October 26-29.

“The Shape of Food to Come: On Drones, the Mediation of Nature, and Data Farming,” Sensor Publics, Technische Universität München, Munich, Germany, April 5-7.
“As Below, So Above: Media Farms, Agriculture Drones, and the Quest for Transparent Nature” Society for Cinema and Media Studies, Chicago, IL March 22-26.

Organizer and Chair, “Transparency and Opacity” panel, Society for Cinema and Media Studies, Chicago, IL March 22-26.

2016 “Data Farm: Drones, Ecology and the Future of Food” midweSTS workshop, Chicago, IL September 16-17.

“Where Does a Body End? On access, accessories, and living media” 4S/EASST, Barcelona, Spain, August 31 – September 3.

2015 “Digital Accessories: On Access as Apparatus,” Virginia Gunderson Lecture, Bloomington, IN October 16.

“Drone Genealogies: On the Politics and History of an Apian Metonym” Drone War Symposium, Bloomington, IN July 14-17.

2014 “On Biotechnology and the Mediation of Life” Cultural Studies Association, Salt Lake City, UT May 29-31.

2013 “The Algorithms of Middle Earth” Landscape, Space, and Place, Bloomington, IN March 8-11.

TEACHING

Indiana University

I202 “Introduction to Social Informatics,” Associate Instructor, Indiana University. Discussion leader for undergraduate introduction to social, cultural, and political aspects of information technologies. Created and led remote, multi-platform activities during COVID-19 pandemic. Fall 2017, Spring 2021, Fall 2021.

I453 “Computer and Information Ethics,” Instructor of Record, Indiana University. Undergraduate course designed to introduce students to ethical theories and issues in relation to digital technologies, to help students identify and express their own ethical values and perspectives, to develop student stances on ethical issues, and to cultivate skills in critical analysis, communication, and persuasion regarding ethical issues in informatics. Managed 4 graduate Associate Instructors. Fall 2019, Spring 2020.

I495 "Informatics Senior Capstone," Associate Instructor, Indiana University. Year-long undergraduate capstone course across which student teams collaboratively conceive, design, and build a real-world digital program, application, or service. Served as project manager mentoring and assisting seven teams during 2nd semester portion of the course. Spring 2018.

I590 "Data & Society," co-designer & guest lecturer, Indiana University. Course co-developed with Dr. Eden Medina of Computing, Culture and Society, and Dr. David Wild, chair of the Data Science program. A graduate-level, core-curriculum course for Data Science students designed as a critical introduction to political, ethical, and socio-cultural issues in data science. Emphasizes concerns about big data, algorithmic culture, privacy, and more through case studies, projects, and in-depth student discussion. Spring 2018.

C315 "Advertising and Consumer Culture," Instructor of Record, Indiana University. Undergraduate course engaging students with social, political, and historical issues in consumer society and the study of culture; develops critical media analysis skills for reading advertising and related modes of persuasive communication. Special focus given to issues of branding, ethical consumption, digital tracking & ID technology, and the place of non-human animals in capitalism. Fall 2015, Spring 2016.

C190 "Introduction to Media," Instructor of Record, Indiana University. Undergraduate course introducing key theories and histories of film, television, and digital media. Strong emphasis on intersectional representation of gender, race, class, and sexuality, and contemporary changes to the media-technology landscape. Fall 2013, Spring 2014, Summer 2014, Fall 2014 (Associate Instructor), Spring 2015.

C121 "Public Speaking," Instructor of Record, Indiana University. Undergraduate course developing student persuasion and oratory skills. Fall 2012, Spring 2013.

SUNY Oswego

ENG386 "Film Theory," Adjunct Instructor, SUNY Oswego. Undergraduate course surveying theories of moving image media from the 1890s – present. Covered major areas including Soviet Montage, French New Wave, and genre theory, with special focuses on questions of moving image materiality, the ‘post-theory’ historical turn, and the human/animal divide in film. Fall 2009.

ENG102 “English Composition,” Adjunct Instructor, SUNY Oswego. Undergraduate introductory course to writing and composition at the college level. Fall 2009.

SERVICE

2017-2018 Graduate Student Representative, Graduate and Professional Student Government, Indiana University. Member of the Benefits Committee, representative for Communication and Culture and the Media School.

2013-2018 Co-Curator, Underground Film Series, Indiana University. A yearly series at the IU Cinema showcasing underground, avant-garde, experimental, little-seen and similarly strange, subversive, queer, and non-normative films.

2017 Organizing Committee Chair, midweSTS Graduate Student Workshop, Indiana University. Lead member responsible for organizing and overseeing student-led Workshop, Sept. 29-Oct. 1.

2014-2016 Co-founder, Excess Arts Space, Bloomington, IN. A horizontally organized, multi-use, collaborative space focused on art, culture, food, and politics, free and open to public use.

2015 Guest, “Drones at Liberty” *Interchange*, WFHB Bloomington, IN. Shared current research about the politics of drones on local radio program, July 21.

2014 PhD representative, Media School Graduate Student Advisory Board, Indiana University. Graduate student representative for the Dept. of Communication and Culture, advocated for graduate student concerns during Media School merger process.

PROFESSIONAL ASSOCIATIONS

Member, Society for Cinema and Media Studies
Member, Society for the Social Studies of Science
Member, Society for the History of Technology

LANGUAGES

English, Native. German, Spoken and Reading.