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Capital Growth: Precision Agriculture and Vertical Farming in the Corporate Food Regime

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CAPITAL GROWTH: PRECISION AGRICULTURE AND VERTICAL FARMING IN THE CORPORATE FOOD REGIME

by

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ABSTRACT

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Agriculture in the 21st century has entered a digital age. New technologies emphasize GPS, big data, cloud computing, the Internet of Things, automation, sensors, and robotics, contributing to two modes of modern food production known as precision agriculture and vertical farming. Through an interdisciplinary review of scientific and social scientific scholarship, this paper examines the ways in which these two technologies interact with the global corporate food regime and explores their impact in core, peripheral, and semi-peripheral countries. It also engages in a discourse analysis of promotional materials and interview statements from precision agriculture and vertical farming firms to expose the ideological trends behind the development of these technologies, namely neoliberalism, rationalization, and green capitalism.

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CHAPTER 1: INTRODUCTION

1.1 The Role of Technology

Constant technological innovation and social transformation are some of the most enduring byproducts of capitalism. In the preface to the first edition of *Capital*, Karl Marx explains that "Modern industry never looks upon and treats the existing form of a process as final. The technical basis of that industry is therefore revolutionary, while all earlier modes of production were essentially conservative" (2011, p. 532). The need to innovate - stimulated by the profit motive - is an intrinsic quality of the capitalist mode of production, and as the history of the world since the Industrial Revolution has shown, technological innovation has the power to change, disrupt, and revolutionize existing ways of life. Although Marx provides a useful foundation for understanding the machinations of capital, the global economy has changed radically over the last century and a half. The physical (tools, machinery, transportation) as well as institutional (financial instruments, corporate structures, transnational organizations) technologies of the 21st century are evolving rapidly and tumultuously. This is no less true of agriculture than it is of more traditionally industrial sectors, as agriculture is now well into its industrial age. In fact, it may be passing into a new, cybernetic age defined by automation, big data, and the Internet of Things. Though farmers have toiled in the field for 10,000 years, future farmers may be more at home behind a keyboard or inside of a laboratory.

This paper seeks to understand the technologies that are shaping the future of food production. Specifically, it will look at two technological trends: precision agriculture and vertical farming. Both techniques largely consist of measuring and regulating all aspects of the growing process, with vertical farming taking the level of control to the extreme. Advocates of these technologies often praise them as revolutionary. They say that they will change the way that humans grow, distribute, and consume food forever. Meanwhile, the shareholders in the companies developing these technologies stand to gain unimaginable sums of money. This paper endeavors to answer the following questions: What exactly are these technologies? What economic and social forces influenced their development? What impact are they likely to have on the global food system? And what ideological trends can be inferred from these developments?

1.2 Theoretical Framework

This paper utilizes the concept of *food regimes*, as established by Harriet Friedmann and Philip McMichael (1989). In essence, a food regime is a historical period of food production, consumption, and capital accumulation within an interconnected world-system that contains unique characteristics. This theoretical model draws on the intellectual tradition of World-Systems Theory and Marxian economic analysis. In particular, it focuses on the ways in which capital is accumulated through exploitative processes on a global scale. It places a significant emphasis on power relations between core and peripheral countries. In short, because core countries have more highly developed economies, political systems, and military powers, they are able to set the terms of transactions with the periphery. As a result, peripheral countries are unable to accumulate sufficient capital to move beyond simple resource extraction into more advanced forms of industrialization, and the balance between the exploiting core countries and the exploited peripheral countries remains unchanged (Wallerstein, 2004). However, the particularities of production and the relations between countries change over time. These changes allow us to separate historical eras into different food regimes.

Friedmann and McMichael have identified three food regimes since 1870: The British-centered food regime (1870-1930s), the U.S.-centered food regime (1950s-1970s), and the corporate food regime (1980s-present) (McMichael, 2013). This paper will focus on the contours of the corporate food regime currently in place. It will explore the ways in which it operates, the technologies that make it possible, and the ideological forces driving it. An awareness of the global food system is necessary to obtain an understanding of the role of emerging technologies in an international context.

Next, we will explore the problems facing the global food system in the 21st century and the ways in which those problems have been created or exacerbated by the corporate food regime.

1.3 The 21st Century and the Corporate Food Regime

By 2050, the the world's population is expected to reach nearly ten billion people (UN, 2017). While the population will grow around 30%, global demand for agricultural products is expected to nearly double, as increasing incomes in some areas of the semi-periphery, particularly China, drive demand beyond today's productive capacity (Tilman & Clark, 2015). Although agricultural productivity has continually improved alongside population growth, yields have plateaued in recent years, compelling some to wonder whether we've reached the limits of productivity (Mueller & Binder, 2015). Meanwhile, the intensification of agriculture, along with deforestation, is pumping more greenhouse gas into the atmosphere, driving global climate change and threatening the future of the planet. This raises a number of questions about the future of food and the global capitalist system. Can we sustainably support a population of ten billion people without intractably damaging the earth's natural environment?

Today, almost 800 million people, or 11% of the world's population, suffer from persistent hunger, and over two billion people deal with micronutrient deficiencies resulting from insufficiently nutritious diets (FAO, 2017). In spite of these figures, it is widely recognized that there is more than enough food produced daily to provide everyone on earth with ample sustenance. However, the limiting factor for hungry people across the globe is wealth. Although plenty of food exists, many people simply do not have enough money to purchase it. Meanwhile, obesity in both the core and periphery continues to surge. How is it that undernutrition and overnutrition can coexist side-by-side? Clearly, there are significant inequalities and inefficiencies built into the global food system.

While hunger and scarcity have defined humans' relationship with food for millennia, a new set of concerns have spread throughout both the core and periphery. Sometimes described as the "triple burden of malnutrition," undernutrition, micronutrient deficiencies, and overweight and obesity all exist alongside one another, though in varying configurations, around the globe (FAO, 2017). In core countries like the United States, 36.5% of all adults are obese, while 12.3% of households experience food insecurity (CDC, 2017; MacDonald & Hoppe, 2016). In peripheral countries with high levels of wealth inequality, the situation is even more polarized. In Guatemala, for example, 27.1% of school children are overweight, and an additional 7.5% are considered obese. Meanwhile almost half of Guatemalan all children suffer from stunted growth due to food insecurity (Mazariegos, 2016; USAID 2017). High levels of wealth inequality, coupled with increasing consumption of highly processed foods in place of traditional whole foods, results in a world simultaneously suffering from over and undernutrition.

In addition to poverty, structural barriers prevent food from being efficiently and equitably distributed. Poor infrastructure, technology, logistics, behavioral patterns, and inefficient production and distribution result in around one-third of the world's food going to waste somewhere along the food chain (HLPE, 2014). Losses are especially high in peripheral countries where they can can reach nearly 50%. However, some traditional sustainable practices produce losses as low as 2%. Some scholars believe losses are exaggerated in peripheral countries and dismiss the "myth of the soft third option," (Evans, 1998, p. 198) which purports that food insecurity can be eliminated if the problem of food waste is solved.

One of the most pressing issues regarding food production in the 21st century is climate change. Currently, agriculture is the largest contributor of atmospheric methane and nitrous oxide, which trap heat around 84 and almost 300 times more effectively than CO_2, respectively (EDF, 2017; US EPA, 2017). In some parts of the world, particularly peripheral zones like the the Caribbean, the Sahel, and the Arctic, changing climate patterns and climate disasters are already affecting food production and catalyzing unrest over access to resources. The effects of climate change are not simply limited to an increase in global temperature. Increased variability in precipitation, resulting in more frequent floods and droughts, are expected to harm agricultural productivity. Furthermore, changing climates may make certain crops unsuitable to their newly changed environments, making it necessary to invest into reconfiguring agricultural activity.

In addition to driving climate change, atmospheric pollutants, as well as chemicals that contaminate soil and water, pose a considerable threat to the health and wellbeing of all life on the planet. Pesticides on commercially grown crops have been shown to reduce native bee populations (Woodcock et al., 2017), portending a potential agricultural and ecological disaster in which natural pollination ceases. Meanwhile, farm workers that apply toxic chemicals to crops face maladies ranging from skin and eye irritation to cancer and birth defects (US EPA, 2013). Runoff from synthetic nitrogen fertilizers causes dead zones in bodies of water, where algal blooms feed off of nitrogen and suck oxygen from the water, killing off fish and other aquatic life. One of the most enduring criticisms of the Green Revolution is the way in which it made agriculture highly dependent on chemical inputs that contaminate the natural environment, and although there is now some recognition of the harm created by these inputs, they continue being used in greater and greater quantities. Around 25 million people are estimated to suffer from acute pesticide poisoning each year. In America alone, the USDA calculates that 50 million people receive their drinking water from underground reservoirs that may be contaminated with pesticides and other harmful agricultural inputs (Alavanja, 2009).

Not only are our water sources being contaminated, many places around the world are rerouting vital waterways and overpumping aquifers in order to provide adequate irrigation to meet the demands of the market. For instance, the North China Plain, which produces half of China's wheat and one third of its corn, is home to a number of aquifers that are being depleted at an unsustainable rate (Brown, 2012; Huang et al., 2015). Some of these aquifers are home to groundwater that was deposited thousands or tens of thousands of years ago (Currell et al., 2012). Similarly, the planet's soil is being depleted at an alarming pace. The UN's Convention to Combat Desertification reports that around 20% of cropland is decreasing in productivity. It links declining productivity directly to monocropping, the overuse of fertilizers and pesticides, and "the focus on short-term production and profit rather than long-term environmental sustainability" (UN CCD, 2017, p. 11).

This simple explanation reveals the source of many of the global food system's failures. When profit is placed above all other concerns, things like sustainable water usage, nutritional considerations, and sensible pollution standards fall by the wayside. Arguably, these problems stem from the unsustainable practices that were largely ushered in under the corporate food regime.

Unlike previous eras that focused almost exclusively on increasing yields, innovators in the 21st century are tasked with considering a multitude of sometimes conflicting goals. Ideally, innovators would seek to address the myriad problems facing the planet with an eye toward sustainability and equity, creating a world with safer, more abundant and accessible food for everyone. However, the capitalist world-system prioritizes profit above all else. That is not to say, however, that sustainable technology is not an important part of 21st century food production. In fact, according to Harriet Friedmann, we've entered a phase of "green capitalism" (2005, p. 229), in which environmentalism, fair trade, consumer health, and animal welfare have come to define a new era of consumerism, if only superficially. Interestingly, many innovations in modern food production seek to escape the current epoch we've come to inhabit, either by harkening back to an earlier, more innocent and less artificial past, or by looking ahead to a clean, efficient, and hyper-productive future. Although the technologies discussed in this paper have been designed with profitability in mind, a deeper look reveals that there are other ideological concerns involved in their development.

1.4 Ideology

What is ideology? Often, this word is simply used to describe a belief system. Other times, it is used to disparage someone's way of thinking. To claim that someone's thinking is "ideological" implies that it has been corrupted by subjectivity. Sometimes, ideology is thought of as a set of mental models that shape our understanding of the world, usually without us even realizing it. As Terry Eagleton points out, one way in which ideology is distinct from everyday belief is that ideology is mobilizing (1991). It not only shapes what we think but how we act, actively modifying the ways in which we behave and interact with the world.

Although this paper deals rather extensively with ideology, I am not particularly concerned with identifying a single correct definition of ideology. For my purposes, ideology is like a geode. The outside is visible, identifiable, and not especially remarkable. The sparkling inside, however, is only revealed once the geode has been broken open, and that is where all of the really interesting bits are. In other words, people are usually aware of their own ideological views, but those ideologies are often built on numerous unexamined beliefs and assumptions. This paper seeks to identify the prevailing ideologies within precision agriculture and vertical farming while exploring some of their underlying assumptions.

CHAPTER 2: PRECISION AGRICULTURE

2.1 An Introduction to Precision Agriculture

Imagine a traditional family farm. Each day, family members wake up with the sun and begin work on a variety of tasks. Whether they're feeding chickens, milking cows, pulling up weeds, sowing seeds, or harvesting crops, there is a certain routine and familiarity. This is the farmer's land, and he knows it intimately. His knowledge consists of a combination of science and tradition passed down from generation to generation. He spends every day getting to know the specifics of his farm. He knows where the water pools after a big rainstorm and which fields produce the best crops. The farm is small enough that he, along with his family, can tend to everything themselves, with maybe a little help during the harvest season.

This idyllic image of a family farm still exists, to be sure, but it is disappearing fast. One hundred years ago, the average American farm was around 140 acres (USDA, 1935). Today, it is 434 acres (USDA, 2012). Modern farms, particularly in America, have become far too large for a farmer to have intimate, first-hand knowledge of its particularities. Of course, farmers have had tractors and other labor-saving devices for over a hundred years now, making it possible for farms to grow exponentially larger. However, mechanization did not address the issue of knowledge. It allowed farmers to manage huge swaths of land, but it did nothing to help them understand it. As a result, as farm sizes increased, farmers treated each acre in a field more or less the same. This mode of farming became colloquially known as "industrial agriculture" in recognition of its increased productivity alongside the increased environmental devastation that came with excessive tillage and input application.

If 20th century agriculture was defined by mechanization and industrialization, the 21st century may be defined by the introduction of digital technology. Today, 71% of American farmers have access to the internet, and 47% of farmers use computers in their business (USDA, 2017). Aside from the common desktop, laptop, and tablet computers that are designed for home or office use, a new array of farm-specific technologies are gaining prominence in the agricultural sector of core countries. These technologies include GPS, big data, cloud computing, the Internet of Things, automation, sensors, and robotics. This constellation of technologies is used in a method of farming known as "precision agriculture." In essence, precision agriculture can be defined as a method of achieving optimal agricultural efficiency by measuring and adapting to the inherent variation that occurs in nature through the use of digital technology.

This chapter seeks to describe the technologies that make up precision agriculture while examining its place in the overall global corporate food system. The interconnected nature of the global economy means that technological change in one part of the world can have a ripple effect, affecting the livelihoods of workers on the other side of the planet. Moreover, as neoliberal capitalism engulfs virtually every aspect of life, its concomitant ideologies of market supremacy and rationalization come to inhabit the minds of people across the globe. The technologies that make up precision agriculture, then, reify the prevailing ideological character of the corporate food system of the wealthy core countries in which they have been developed.

As noted above, conventional agriculture treats fields with more or less uniformity. If fertilizer is applied, it is applied relatively equally across a given plot. The same goes for water, pesticides, herbicides, fungicides, and other inputs. However, new technologies, through the use of powerful data processors and cloud storage, can record minute variations in fertility, moisture, color, and yield and automatically re-calibrate the application of inputs as necessary. Much of this new technology operates thanks to the Internet of Things, a concept which has gained increasing prominence in recent years in fields as diverse as home appliances, wearable fitness tech, and agriculture. The Internet of Things consists of a network of machines and everyday objects that are wirelessly connected to the Internet. These objects are capable of sending and receiving information, creating a database of information so enormous that no human could possible analyze it. However, with sufficient computing power, the "big data" produced by the Internet of Things can reveal powerful trends and help direct the efficient use of resources. On a farm using precision agriculture, all of the digital devices involved in monitoring, planting, maintaining, and harvesting food and other commodities are connected through the Internet of Things, creating a detailed virtual picture of the farm's productive capacities.

So, how does a farm fully outfitted with all of the latest precision agriculture technologies operate? First, before anything is planted, the soil is tested to reveal characteristics like acidity and nutritional composition. This is not unique to precision agriculture and has been a common farming practice for decades. Often, several samples are taken from a variety of locations in order to identify natural variations in soil fertility (Ferguson et al., 2009). However, an innovation of precision agriculture involves the use of wireless in-field sensors that measure conditions in real time. The field may contain one sensor per acre or even more to achieve a high level of precision, or sensors may be less frequent due to high costs. But like most technologies, wireless sensors will become more affordable over time. They will also continue to advance in utility, with some modern sensors monitoring a variety of conditions beyond soil composition such as moisture, fertility, and temperature. Already, improvements in affordability and sustainability have produced solar powered sensors to replace earlier versions that ran on conventional lithium batteries (Srbinovska et al., 2014; Jawad et al., 2017). One particularly useful data point is nitrogen content (Hedley, 2014), and a number of apps have been created to continually measure this essential nutrient. As the information is collected, it is transmitted in real time to the farmer's laptop or tablet as a heat map, so he or she can monitor their field from anywhere at any time. In this way, a farmer can gain insight into the minutiae of the conditions in his or her field without even stepping foot in it.

Next, the farmer must plant seeds. With the knowledge of differential productivity levels within the field, farmers can use a technique called variable-rate seeding. To accomplish this, the farmer attaches a special seeder to their tractor. This seeder is outfitted with software that is synced with the information collected by soil testing and monitoring, providing it with a guide to the soil's fertility rates. The seeder then automatically distributes seeds accordingly, allocating more seeds to more fertile areas and fewer seeds to less fertile areas. In some cases, different seed varieties of the same crop, such as corn, may be automatically planted in more suitable areas within the same field. This practice is known as "prescription planting" (Schimmelpfennig, 2016). These techniques allow the farmer to make use of the information collected by in-field sensors and take full advantage of the most productive parts of the field.

The whole process is relatively autonomous. The tractor that pulls the seeder is fitted with a GPS guidance system and auto-steer. In addition to freeing up the farmer to monitor all of the ongoing processes instead of focusing on steering, self-driving tractors allow for extreme precision and ensure that no areas are missed or double-seeded. The same principle applies to the application of other inputs. This precision saves the farmer money by eliminating the wasteful over-application of seeds and inputs due to human error.

Although this method is virtually autonomous and extremely efficient, innovations in robotics may make the use of tractors in seeding obsolete. The German agricultural machinery manufacturer, Fendt, has developed Mobile Agricultural Robot Swarms (MARS) as part of its Project Xaver. MARS consists of a number of autonomous vehicles, each about the size of a large dog, that operate synchronously to plant seeds. Because there are several of them, they can seed an entire field much faster than a conventional tractor, and due to their small size, they require relatively little energy and only very lightly compact the soil as they move through the fields. They also keep a log of each seed planted, making it easy for farmers to access data about their field. Although MARS is not yet available for purchase, it has been field tested, and Fendt is currently accepting inquiries from interested parties (Fendt, 2018).

Once the seeds are planted, famers can continue to track the crops' progress through the information produced by in-field sensors. Farmers have also begun to use drones to produce high-quality bird's eye images of their fields for mapping, monitoring, and administering targeted applications of pesticides and other sprays. Some technologies have even been created to recognize areas infested by insects or other pests through the use of visual sensors, enabling drones to automatically apply targeted pesticides (Atherton, 2016). Sensors can also, in some cases, determine a plant's health by the color of its leaves, with yellowing leaves signifying an insufficient supply of nitrogen (Chong, 2016). Using this information along with soil nutrient measurements, variable-rate technology can be utilized to apply fertilizer and other inputs to different areas so that they get exactly what they need to produce healthy crops.

Although many of the large grain fields that use precision agriculture technologies are located in areas that do not require irrigation, around 28% of all crops in America still require some sort of irrigation (USDA ERS, 2017a). The most common type of precision irrigation is "drip irrigation," which aims to limit the amount of water wasted by targeting water flows directly where and when they are needed. Drip irrigation lines can run above or underground, with underground lines being the most efficient, since they virtually eliminate water loss due to evaporation. They also prevent overwatering and reduce runoff. However, underground drip irrigation lines are also more expensive to install and maintain. Through the Internet of Things, drip irrigation systems can also be connected to in-field sensors that measure soil moisture. Once moisture levels dip below a certain level, the irrigation system is automatically activated, sending water only where it is needed until that area reaches its optimal moisture saturation level (Panagiotis et al., 2016).

When it's time for harvest, the GPS-enabled tractor with auto-steer pulls a combine harvester that comes equipped with more sensors. Like other sensors, these are designed to measure variations in the field. In this case, the harvester measures how productive each part of the field is by measuring the weight of the yield. This creates another heat map that the farmer can use for future seasons, letting him or her know exactly which parts of the field are the most productive so that they can take steps in the future to mitigate particular deficiencies. It also provides a guide for any future farmers who may purchase or inherit the land. Some concerns have been raised in recent years over who has access to the vast amount of data being collected by the Internet of Things. The Open Ag Data Alliance advocates for farmers, arguing that they should own any data generated on their farm, but they should also have the right and ability to share that information with other farmers or business partners at their discretion. While some farmers are concerned over privacy, if used properly, this information could lend greater insight into soil degradation or other environmental trends that may not be obvious without access to this kind of widespread data.

2.2 Precision Agriculture in the Global Corporate Food Regime

Clearly, this type of technology is not suitable for all farms. It favors large, monocropped farms that grow crops that do not need to be harvested by hand. Growers of more delicate, hand picked fruit and vegetables like tomatoes or grapes may take advantage of the some of the above technologies, particularly those related to assessing soil quality and yield variations (Gemtos et al., 2013), but some of the other technologies are irrelevant to perennial plants and trees. Moreover, the profit margins for small farms are often very narrow, putting investment in precision agriculture out of reach for many farmers. Additionally, famers on small plots of land can more easily monitor and control their fields. A farmer with a few acres of land is much more likely to have a strong understanding of the strengths and weaknesses in his or her field than a farmer with a thousand acres. Unsurprisingly, then, precision agriculture has largely been adopted by farmers of grains, particularly corn and soybeans.

In addition to farm size, geographical location (along with all of its accompanying social, political, and economic attributes) plays a major role in determining the adoption rate of precision agriculture. In the United States, around half of all corn farms have adopted at least one precision agriculture technology. Specifically, adoption rates are 48% for yield monitoring, 25% for yield mapping, 19% for soil GPS mapping, 29% for guidance systems, and 19% for variable rate technologies (Schimmelpfennig, 2016). In Germany, between 10% and 30% of farmers use some form of precision agriculture (Paustian & Theuvsen, 2016). In Australia, as much as 90% of farmers use auto-steering (Bramley & Trengove, 2013). Meanwhile, peripheral and semi-peripheral countries lag far behind, with official adoptions numbers in countries such as India and Brazil unavailable but presumed to be very low despite gradually growing (Mondal & Basu, 2009; Borghi et al., 2016). China faces a major challenge in adopting precision agriculture technologies because of its smallholder system. Land reform in the early 1950s reallocated a significant amount of farmland to previously landless peasants. These farms were divided into tiny parcels, making Chinese farms some of the smallest in the world. Nearly seventy years later, despite the failed collectivization policies of the Great Leap Forward, little consolidation has taken place, and Chinese farms still average less than two acres per farm among around 200 million farmers (Wang et al., 2014). This makes it economically as well as logistically impractical for most Chinese farmers to adopt modern techniques.

There are two significant points to consider about the adoption of precision agriculture within the international market-based corporate food regime. First, the early adopters consist of core countries that tend to be major grain producers. These countries, such as the U.S., Canada, and Australia, largely based their food production on a model of self-sufficiency plus grain export. In the U.S., in the years immediately following World War 2, exports were emphasized and explicitly conceived of within a food aid regime that sought to rebuild Europe and Asia, establish good diplomatic relations between the U.S. and those regions, and stop the spread of communism. In the 1980s, that model transitioned from a regime based on reduced-price food aid to one based on market-price international sales, often to the same countries that once received aid. In a rush to industrialize, many countries abandoned their agricultural sectors, making them reliant on core countries - the U.S. in particular - for staple foods. Egypt, for instance, imported 1.5 million metric tons of wheat from the U.S. each year in the early 1980s, accounting for one-third of the country's total wheat consumption (Crittenden, 1981). In fact, Egypt's food security has remained precarious ever since, with massive inflation in the price of wheat being a major cause of the Arab Spring uprisings in Tahrir Square in 2011.

In short, the U.S. has had the infrastructure in place for over seventy years to produce large amounts of grain for export. Today, the U.S. produces 53% of global corn exports and 23% of wheat exports (Clapp, 2016). Additionally, the U.S. exports 26.6% of the pork, 12.9% of the beef (USMEF, 2017), and 18% of the poultry that it produces (USDA ERS, 2017b), almost all of which is fattened on American-grown corn and soybeans.

American farms have also become more suitable for precision agriculture as they grow in size. Consolidation has been going on for decades, as small farmers are pushed out of the market by large corporate farms that can take advantage of economies of scale and are able to afford the most cutting edge agricultural technologies and undersell their competition (Duffy, 2009). Inevitably, this leads to bankruptcy for small farmers, forcing them to sell their land, which is often purchased by larger farmers. The resulting enormous farms in areas with suitable growing conditions for corn and soybeans are ideal settings for the adoption of precision agriculture. In the United States, the percentage of acres farmed using precision agriculture is much larger than the percentage of farms using precision agriculture. This means that these technologies are being adopted by large farms that cover hundreds or thousands of acres at much higher rates than by small farms. In fact, the largest corn farms in the country, those over 2,900 acres, are twice as likely to adopt precision agriculture techniques as the average farm (Schimmelpfennig, 2016).

Meanwhile, peripheral and semi-peripheral countries are often poor candidates for the adoption of precision agriculture. The primary reason is that most farmers simply lack the necessary capital to invest in new technologies. It is difficult to say exactly how much it costs to introduce precision agriculture technologies since there are so many variables, and most farmers take an *à la carte* approach, only adopting the technologies that are profitable for their specific needs. But the average price of a GPS-enabled auto-steer addition (not including the tractor itself) is a few thousand dollars. Wireless sensors are more affordable, starting at around $100 per sensor, but without the accompanying software and hardware (a laptop, at least), they are useless.

The average gross income of a smallholder family farm in Kenya is $2,527 per year (Rapsomanikis, 2015). This number is fairly representative of peripheral countries, where even basic mechanized farm equipment is often scarce. In Central Africa, for example, 80% of all agricultural work is done by hand (FAO, 2011). This presents a major barrier to entry, as the adoption of basic mechanization is a prerequisite for the eventual adoption of precision agriculture technologies. Furthermore, precision agriculture requires significant infrastructure in order to operate. Specifically, consistent electricity and wi-fi internet access are absolutely necessary so that the various devices connected to the Internet can continually measure, interpret, and share information with one another. Even in core countries, rural off-the-grid areas exist in which these necessities are not available, particularly for indigenous people such as those, for example, in the less accessible parts of Canada (Currie, 2014). In peripheral countries, widespread rural access to wi-fi is often an unimaginable luxury.

Overall, despite their high initial costs, net returns on precision agriculture technologies are fairly low. In the United States, GPS mapping technologies generate a net return of only around 2%, while guidance systems contribute a 1.5% increase, and variable-rate technology raises net returns by 1.1% (Schimmelpfennig, 2016). Although this may seem negligible, even 1% is not insignificant for a farmer with a large farm who nets over a million dollars per year. An article in the John Deere Journal boasts that these technologies pay for themselves after a period of half a year to four years, depending on the fertility of the farm ("The Payoff from Precision Agriculture," 2015).

Of course, not every farmer has tens or hundreds of thousands of dollars to invest in new technologies. In fact, most American farms are family-owned, with only around 10% of all farms being large-scale industrial operations. This differential adoption rate creates a scenario in which the richest farmers, which make up a minority, are able to continually increase their profits by replacing labor with machines, while poorer farmers struggle to compete. In 2015, the 90% of small, family-owned farms produced only 24% of all value in the agricultural sector. Meanwhile, the 2.9% of farms that gross over $1 million annually contributed 42% of all productivity (MacDonald & Hoppe, 2017). As large farms continue to produce major profits, they will continue to buy out smaller farms, consolidating fields into even larger properties. Richard Nixon's Secretary of Agriculture, Earl Butz, put it bluntly but presciently, that in American agriculture, you have to "get big or get out" (Scholar, 1973).

This principle also has an international dynamic. As the market for food commodities has taken on an almost entirely global character, poor farmers using traditional hoes, sickles, and oxen in peripheral countries must compete with farmers in core countries using self-driving tractors and GPS yield mapping. In response to the requirements of the market, it is unsurprising that national agricultural plans in peripheral countries have come to focus on valuable export crops that often require personal care and attention that cannot yet be provided by machines. For example, Nigeria's Federal Ministry of Agriculture and Rural Development recently released its "Green Alternative" national agriculture plan, which explicitly focuses on producing mangos, avocados, bananas, cashew nuts, and fish for the international market (FMARD, 2016), all food products that benefit from intensive human labor but not intense mechanization. The goal is to make Nigerian food an internationally recognizable food brand, like Colombian coffee or Chilean wine.

The focus on high-value, labor-intensive crops in peripheral countries is fairly widespread. There 21 countries in Sub-Saharan Africa, 14 in Latin America and the Caribbean, and 6 in the South Pacific Islands that rely on a single commodity for over half of their agricultural export revenue. This includes Burundi, which earns 83% of its export revenue from coffee, St. Lucia, which earns 84% from bananas, and Tonga, which earns 66% from pumpkins (FAO, 2002). None of these are grain or oilseed crops, and thus all require significant human labor that cannot be replicated by machines. Although there are obviously environmental factors that determine where certain crops can and cannot grow, there also exists an economic calculation that dictates where it is profitable to grow crops that rely on human labor rather than machines.

In short, this means that rich farmers in core countries are able to produce more grains with less labor for the international market. Since grains make up around half of the average person's diet (and even more in poor countries), peripheral countries must import their basic food staples simply in order to continue simply living. This makes them dependent on core countries, tying their political and economic futures to wealthy and powerful countries that are free to cut off their food supplies if they pursue national policies that do not coincide with the interests of the core countries.

Usually, this strategy of producing high-value crops in place of staple foods is paired with an effort to industrialize. The reasoning is that peripheral countries should use their comparative advantage to focus on producing valuable crops for the world market while investing in manufacturing. This idea is derived from Modernization Theory, which posits that in order for poor countries to flourish, they must follow in the footsteps of rich countries. This process includes industrialization and strict adherence to free-market fundamentals. It is a narrow view of national development that claims that there is only a single path to modernity. Unfortunately, this developmental model has not been very successful, and the Structural Adjustment Programs based on Modernization Theory have overwhelmingly failed to produce good outcomes in peripheral countries (Stiglitz, 2003).

Like the division between small farmers and large farmers, there is a fundamental difference in productivity between core and peripheral countries. Core countries more effectively create and extract surplus value, resulting in capital for investment in machinery that produces even more surplus value. Peripheral countries cannot follow the examples of core countries because they must compete with the core countries on terms established by core-run transnational organizations like the WTO. In reality, core countries did not become rich through competition in the free market. Countries like the U.S. and the U.K. relied heavily on protectionist trade policies to grow their infant industries and only removed trade barriers once they had established economic supremacy (Chang, 2002). This means that the strategy of de-emphasizing self-sufficiency that many peripheral countries are pursuing leaves them food insecure and does not promote real economic growth.

For struggling peripheral countries, things have become even more dire over the last decade, since grain and soybean prices doubled in 2007-2008. This led to demonstrations across the world, including the protests known as the Arab Spring. In an attempt to insure against future grain shortages and resulting price spikes, countries such as China, South Korea, Saudi Arabia, and India have been purchasing or leasing arable land in some of the poorest peripheral countries in Africa, Latin America, and Southeast Asia (Brown, 2012). India, for instance, has acquired 300,712 hectares (1,161 square miles) of farmland in Ethiopia (Hules & Singh, 2016). Often, these lands are already occupied, but since many small landholders in peripheral countries do not have official deeds to their properties, they can be driven off of the land that their family has inhabited for generations. As a result, although mechanized farming technology is sometimes imported to these peripheral countries for use on newly bought land, it stays out of the reach of local populations. Additionally, although net production might increase in these countries, overall food security may decrease, as the crops grown for food and biofuels by foreign landholders inevitably leave the country (Marselis et al., 2017).

2.3 Precision Agriculture and Ideology

Technology is not value-neutral, and it is not developed in a vacuum. It reflects both the material conditions and the ideological convictions of its creators. In exploring the ideology or ideologies behind precision agriculture, it is useful to consider where these technologies came from and the motivations behind their creation. As the development of precision agriculture has largely taken place in wealthy core countries, it was clearly designed to address issues of importance in those same core countries. Primarily, as a country that had focused on grain export for decades, the main agricultural interest of the United States has been increasing yields. In the Cold War era, more yield meant more food aid to peripheral countries to obstruct the spread of communism (Friedmann, 1989). During the corporate food regime, the basic goal has not changed. More yield means more profit. However, with the international specter of communism virtually vanquished, the ultra-capitalist character of the corporate food regime has been completely normalized. Of course agricultural technology is wielded to produce more profit. What else would it be used for?

The development of precision agriculture also has the effect of reducing the number of necessary agricultural workers. This, similarly, increases profits by reducing labor costs and is part of a much broader trend. Participation in agricultural labor has dropped off dramatically in core countries over the last century, with agriculture employing 1.6% of the population in England (UK DEFRA, 2017), 1.3% in Australia (NFF, 2017), and 1.8% in Canada (Statistics Canada, 2011). By comparison, employment in agriculture makes up 62% of all labor participation in Afghanistan, 75% in Rwanda, and 19% in El Salvador (World Bank, 2018). Core countries and some semi-peripheral countries, despite their vastly smaller proportion of farm workers, produce much more food than peripheral countries thanks to their use of modern labor-saving machinery (Metabolic, 2016). In the near future, the further development of precision agriculture may allow for even fewer workers in the agricultural sector, particularly as robotics become more advanced and potentially capable of harvesting delicate fruit and vegetables like strawberries and cauliflower. Of course, workers have been replaced by technology for ages. While this is a fundamental feature of capitalism, the general public is overwhelmingly wary of widespread automation. In a recent survey from Pew, only 33% of Americans reported that they are enthusiastic about "a future where robots and computers can do many human jobs," while 72% are worried (with some overlap among people who are simultaneously enthusiastic and worried) (Anderson, 2017).

The substitution of technology for labor presents a meaningful contradiction in the capitalist mode of production, since laborers contribute to both production and consumption, but machines do not. Since machines clearly do not consume goods and services in order to reproduce themselves in the same way that workers do, the production-consumption loop that all modes of production rely on is broken. Taken to its extreme conclusion, this results in a system in which plentiful goods are produced, but few people have the money to buy them. Usually, skepticism about the job-destroying potential of technology is rebranded in Schumpeterian fashion as "creative destruction," in which one opportunity disappears but another opportunity appears in its place. Historically, that has largely been the case in agriculture, as farm workers have left the countryside and moved to cities in search of employment in manufacturing and the service industry for centuries. However, now that those jobs are being replaced by automation as well, whether or not this contradiction can hold into the 21st century remains to be seen.

Practically speaking, precision agriculture was designed, beginning in the mid-1990s, with the intention of creating more food more efficiently. Its developers and advocates do not usually address the worldwide issues detailed in the introduction of this paper such as climate change, soil degradation, or nutrition. The main focus is on output, and thus (only incidentally) hunger. This is sometimes augmented with a message about sustainability, but most attempts at green-washing resource-intensive industrial farming come off as insincere. The vast majority of promotional materials for precision agriculture products primarily extoll their capacity for maximizing profits. The underlying ideology expressed here is the neoliberal faith in market supremacy. Farmers are told that, in order to survive, they must purchase the latest technologies. That ensures a competitive edge not only against other local farmers but against farmers around the world. Although farmers are engaged in one of the most essential occupations for the functioning of society at large, their endeavor is seen primarily as an exercise in increasing personal wealth. One is reminded of Adam Smith's famous passage, "It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest" (1977, p. 30). The overriding imperative of neoliberal ideology echoes this sentiment, emphasizing competition and self-determination.

Tech companies are similarly engaged in competitive warfare with one another, as evidenced by the staggering number of startups involved in precision agriculture and other food-related technologies. The goal is not only to create a product that will increase crops' yield but to promote it in an appealing way based on consumers' desires. In the case of precision agriculture, this is largely achieved through the use of three methods - by appealing to the product's utility, its sustainability, and its rationality. I expected to find an appeal to novelty since many of the products, particularly the ones using robotics and automation have a bit of a science-fiction feel and aesthetic. However, an overview of dozens of precision agriculture companies' websites and promotional materials did not show this to be the case. Upon reflection, it makes sense. When it comes to innovation, farmers are preconditioned to be fairly conservative. They cannot risk the use of an untested technology that will result in a financially devastating crop failure. They must have full confidence in the reliability of the product. For that reason, precision agriculture firms are more likely to stoically focus on statistics such as increases in yield and profit.

The most pervasive advertising tactic among precision agriculture products is the appeal to utility. Farmers are, by and large, business owners who are either contracted to produce certain amounts of agricultural commodities or independent producers who must find buyers for their products on the commodity market after they are harvested. They are well aware of the costs and returns involved, and like any business owner, they are interested in adopting techniques and technologies that will boost their profits. Many precision agriculture companies adhere strictly to this market-based ideology through the use of straightforward financial rhetoric. For instance, the agricultural information technology company CropMetrics commands prospective users, “Know your variables. Manage your inputs. Optimize your yields” (2018). This is the precision agriculture equivalent of Nike’s “Just do it.” Although the technology itself is complex, this slogan makes its use seem simple and adopting the technology a no-brainer. However, it also uses words that lend the product legitimacy in both the scientific and business worlds such as “variables” and “optimize.” The slogan is essentially an equation for boosting output, and thus profits. Similarly, the drone-focused company, Agribotix, writes on its website, “Our solutions are designed to deliver real value for farmers — reducing crop inputs, boosting yields, and increasing profits” (2018). These proposals are straightforward and pragmatic, appealing to profit-focused agricultural entrepreneurs.

The second method stresses the sustainability of precision agriculture. With rising public furor over climate change and recurring environmental disasters, even conventional farmers are finding it hard to ignore the public conversation around sustainability. In reality, though, the use of this word in relation to large-scale industrial farming seems like little more than the cynical appropriation of a popular but increasingly meaningless buzzword. It’s questionable whether or not conventional agriculture can in any way be considered sustainable, but the basic argument is that precision agriculture results in the most efficient application of harmful chemicals like pesticides and fertilizers. There is no denying the toxicity of these chemicals, but there is concern over their over-application. Through the use of GPS guidance and variable-rate technologies, no chemicals are applied to the same area twice, and each plant only receives as much of each chemical as is necessary, resulting in a more sustainable use of synthetic inputs. The infometrics company, Agrible, has the word “sustainable” plastered across their website several times, writing that “Agrible's approach to sustainability is one that revolves around collaboration. We partner with all areas of the supply chain, starting with growers at the field level to offer scalable sustainability programs to help prove brand promises” (2018). This melange of buzzwords and corporate jargon contains no indication of what actually makes their supply chain sustainable. To be fair, infometrics companies are mostly responsible for delivering information about farmers’ crops. What the farmers do with that information is up to them, and they can take either more or less sustainable approaches.

Blue River Technology combines a concern over unsustainable farming practices with the realism of market adherence, solemnly writing on its website that, “Over-relying on a handful of broadcast-spray chemicals fuels the evolution of herbicide tolerance. Fighting these weeds hurts farmers' crops and their profitability” (2018). Although the issue of herbicide tolerance is of concern to environmental activists because of the threat it presents to biodiversity, that is of little interest to most large-scale farmers’ bottom line. Clearly, farmers have a vested interest in preserving the environment, but from the perspective of Blue River Technology and its customers, profit comes first.

Last, precision agriculture companies stress the rational application of science-based, data-intensive approaches. Agtech startup, Prospera (whose name immediately announces its primary concern), advocates what it calls "data-powered agronomy" (2018), claiming that their products provide 95% accuracy in predicting future yields. The underlying ideology here is a mechanistic view of the world that views complex, interactive systems as simple, mechanical apparatuses that produce predictable outputs given the proper inputs. Obviously, this view is not entirely false, as farmers have reliably increased yields through scientific and technological innovations for thousands of years. However, it is also a blinkered view of the natural world.

In a way, the history of agriculture is the history of rationalization. Farmers have advanced from broadcasting seeds onto floodplains to meticulously tracking all of the relevant inputs to ensure optimum yields. This process began slowly but increased exponentially starting in the 19th century, as the elemental composition of soil was discovered, synthetic fertilizer was developed, mechanized farm equipment was invented, hybrid crops were created, and now, GMO crops and precision agriculture technologies have begun to spread. Each step in the process of modernizing agriculture represents an increase in rationalization. According to Max Weber rationalization "means that principally there are no mysterious incalculable forces that come into play, but rather that one can, in principle, master all things by calculation" (1958, p. 117). Significantly, rationalization not only involves thinking of the natural world in a mechanistic way but mastering it. It is an ideology that promotes human reason and agency above all else and advocates that the right to reshape nature flows inexorably from understanding it. The prerequisite for mastery, though, is calculation, and calculation requires systems for conceptualizing the myriad problems that must be solved.

Although there are many mental models that modern people have come to use in order to understand the world, perhaps the most pervasive ideological characteristic of modern rationalization is Cartesian reductionism, or the idea that any complex system can be understood by breaking it down and analyzing its constituent parts. For example, a thorough understanding of a plant's leaves, cells, and organelles will reveal the mechanisms behind photosynthesis. In *Discourse on Method*, Descartes compares the natural world to the workings of a clock, with each part interacting in a mechanistic and predictable way (2009). Clearly, there is some truth to this, and this reductionist method can be extremely useful in understanding biological, chemical, and physical processes as well as abstract concepts. In fact, this idea provides the foundation for the scientific method, which relies on an awareness of the constituent parts that make up an experimental whole. However, Cartesian reductionism also provides a simplistic, non-dialectical view of how things interact in the real world. For instance, Cartesian reductionism explains, to an extent, the successes and failures of synthetic inputs in modern agriculture. In the 19th century, scientists discovered that nitrogen is an essential component of soil that contributes to plant growth. A mechanical and reductionist perspective then compels farmers to add nitrogen to infertile soil. This myopic view fixes the problem but does not take into account the broader ecological system that the soil plays a role in. It is virtually impossible for all of the nitrogen-based fertilizer to be absorbed by the plants it is intended for, and much of the remaining fertilizer is washed away, polluting the water system. Other parts turn gaseous, contributing to greenhouse gases in the atmosphere (Li et al., 2017). A similar process can be attributed to monocropping, pesticide and herbicide use, intensive tillage, and many other modern agricultural techniques that were developed to solve one problem but ultimately created other problems. This reductionist way of thinking is an inherent and implicit ideological characteristic of rationalization. Although it drove many of the advances in science and technology in the last several hundred years, it has also resulted in widespread environmental degradation and catastrophic health outcomes.

In the Marxian view promoted by the collective of thinkers known as the Frankfurt School, rationalization not only changes the way we produce, it fundamentally changes who we are. During World War II and in the following decades, Herbert Marcuse wrote extensively on the effects of rationalization and technological innovation on society. He argued that it was the extreme rationalization of German society that led to the compliance of everyday people to the mass killings of the Holocaust. In fact, Marcuse believed that the process described by Weber was in reality irrationality disguised as rationality, and that advanced technologies that alienate and subjugate workers dissolve the conventional individual rationality that characterizes traditional cultures (Marcuse, 1969). In other words, adherence to strict rationality that does not improve the quality of life or social relations between people is not actually rational. This new form of rationality turns people into little more than tools of capital accumulation, and the mechanistic nature of modern technology is replicated in the mechanistic behavior among people. From this "rational" perspective, a person's worth is wholly determined by their ability to produce surplus value. Furthermore, to challenge the system appears to be the most irrational thing one can do, as the system embodies all of the positive characteristics that the ideology of rationalization promotes: speed, efficiency, and convenience (Marcuse, 1941).

As Weber put it one hundred years ago, "The fate of our times is characterized by rationalization and intellectualization and, above all, by the 'disenchantment of the world.'" (1958, p. 16). In essence, by replacing worldviews founded on superstition, myth, and tradition with a worldview based on reason, scientific truth, and rational behavior, people have come to see a more accurate vision of the world as it actually exists. However, once the scales fall from our eyes, we also do away with magical thinking and give up the "sublime values" of mysticism and fraternity. For Weber, the process of rationalization was only able to take place because of certain historical factors, namely Protestantism and capitalism. Thus, for him, capitalism is the necessary condition under which rationalization flourishes. Marcuse writes that:

> In the unfolding of capitalist rationality, irrationality becomes reason: reason as frantic development of productivity, conquest of nature, enlargement of the mass of goods (and their accessibility for broad strata of the population); irrational because higher productivity, domination of nature, and social wealth become destructive forces (1969, p. 155).

Arguably, rationalization is the primary ideological trend that has shaped the world's trajectory since the Industrial Revolution, if not since well before. The proliferation of machinery throughout the world, in all economic sectors, not only reflects a belief in rationalization but reifies it. Agriculture is not in any way unique in this regard. However, the degree to which rationalization transforms or corrupts the mind - or as Marcuse puts it, makes people "one-dimensional" - is debatable. Certainly, modern society is organized in much more rational ways than it was in pre-scientific or pre-industrial times. Still, this does not mean that people always behave rationally or that there is not a significant constituency of people who oppose intensive capitalist rationalization. I also do not want to overstate the degree to which the increasing rationalization of agriculture affects society at large, since, as previously mentioned, the percentage of the population engaged in agricultural production in core countries is relatively small. However, the ideologies embedded in precision agriculture essentially reflect the ideologies of the globalized modern world more broadly.

Moreover, it is interesting to consider to what degree an ideology gravitates toward its ultimate expression. If the data-driven market-based ideology of rationalization is a driving force of technological innovation in the agricultural sector, what is the logical conclusion of this trend? Is it, as Marcuse suggests, a self-destructive drive toward environmental devastation? Or is a more holistic rationalization possible - one that recognizes the importance of sustainable and equitable development?

CHAPTER 3: VERTICAL FARMING

3.1 An Introduction to Vertical Farming

While we've seen the rise of rationalization on traditional farms through the development of precision agriculture, an even more extreme version of rationalization has occurred outside of the realm of conventional agriculture. Advances in computing, automation, and LED lighting have given rise to an entirely new form of agriculture - the vertical farm. In vertical farms, nothing is left to chance or determined by the whims of nature. In fact, plants grown in vertical farms are shielded from the outside world, treated like frail children with overprotective parents. Each step of the growing process is predetermined, measured, and carried out exactly to meet the grower's specifications for optimum efficiency and maximum plant health.

This chapter will begin by exploring how vertical farms function while distinguishing between how they operate in reality versus the vision some techno-futurists are keen to promote. We will see that although vertical farming presents an interesting possibility for food production, there are still many obstacles that must be overcome in order for it to become truly viable. Then, we will examine the role that vertical farming plays in the global corporate food regime. Since the technologies involved in vertical farming are so new, we will also consider the probability of its growth within the agricultural sector in both core and peripheral countries. Last, we will analyze some promotional materials put out by vertical farming companies as well as some statements made by representatives of two vertical farming startups in order to discover the ideologies underpinning the development of vertical farming technologies. As we will see, it shares some significant characteristics with precision agriculture while differing in important ways. Since there are few vertical farming companies in existence at the moment, and because I was able to speak with representatives from two startups, Aerofarms and Square Roots, this section will mostly refer to these two companies when looking at specific examples.

Although the idea of growing food indoors has existed for some time, the concept of the modern vertical farm is usually attributed to Dickson Despommier, emeritus professor of microbiology and public health at Columbia University. In 1999, he and a class of graduate students began working on a project to determine whether enough rice could be grown on New York City's rooftops to feed the teeming metropolis. When the results showed that the potential impact of rooftop farms was relatively negligible, Despommier began to rethink the two-dimensional limits of urban agriculture. What, he wondered, if we grew crops inside of skyscrapers, not merely on top (Despommier, 2011)? Since he and his class of graduate students began to develop the idea, hundreds of designs for vertical farms have been drafted. The basic design includes plants grown in stacked trays or vertical tubes. While traditional agriculture exists more or less on the *x*-*y* axis of a Cartesian coordinate system, vertical farming adds the *z* dimension, turning a 2D plane into a 3D space and multiplying the available space many times over. Building off of Despommier's original idea, designers and engineers have tweaked the details to improve efficiency and make vertical farming a reality.

AeroFarms in Newark, New Jersey is the world's largest indoor vertical farm and probably the quintessential vertical farm as of 2018. Located in an old steel mill, AeroFarms' "global headquarters" harvests up to two million pounds of leafy green vegetables each year. Their homepage proudly proclaims that their vertical farms are "390 times more productive than field farming" (2018a).

AeroFarms specializes in controlled environment farming. This means that virtually all of the factors that affect growth are closely regulated by the growers. These include light, temperature, water, nutrients, space, and the chemical composition of the air. In place of dirt, seeds are planted in a wispy cloth made of recycled plastic bottles. Their roots grow beneath the cloth and are sprayed with an aeroponic mixture of water and dissolved nutrients. Instead of sunlight, the plants sit beneath rows of blue and red LED lights. By removing wavelengths of light that are unnecessary for plant growth, growers are able to use less energy and run cooler systems than if they were using conventional full-spectrum lights.

In addition to controlling every aspect of the growing process, Aerofarms gathers 130,000 data points on each harvest with the goal of catching deviations from optimum growth and correcting them. They write:

> AeroFarms is a marriage of data science, engineering and biology. Even with exacting techniques and precise recipes for nutrients and light, biology introduces infinite variables. By monitoring every aspect of the plant at every moment, we can address the whims of biology in real time to make sure that our leafy greens are uniformly delicious and always up to our high standards (2018c).

One of the most widely touted benefits of vertical farming is its reduced need for certain chemical inputs. Strict control over the growing area allows for reduced pesticide, herbicide, and fungicide use. In some cases, these chemicals may be eliminated entirely (Despommier, 2011). This has a host of benefits. First, some pesticides have been shown to be harmful to human health, particularly to field workers who apply the chemicals to crops (Alavanja et al., 2013), and pesticide residues are often still present when foods arrive in supermarkets (USDA, 2015). Also, increased pesticide use can lead to immunity among pests, making them harder to control. Lastly, pesticides are costly. American farmers spend around $10 billion on pesticides each year (Pimentel, 2005). In general, the arguments against the use of pesticides equally apply to herbicides and fungicides. By reducing or eliminating the amount of harmful inputs, vertical farmers can save money on expensive inputs and while producing food that is safer for consumers as well as workers.

Environmental controls also allow for faster plant growth. Plants photosynthesize at a faster rate when surrounded by increased atmospheric levels of CO_2 (Cure & Acock, 1986). Thus, vertical farms are able to increase yields by optimizing their levels of CO_2. However, recent research shows that while increased CO_2 promotes plant growth, it alters plants' nutritional composition, increasing carbohydrates (starches and sugars) and decreasing concentrations of protein and minerals such as iron and zinc (Loladze, 2014). This means that although produce grown in vertical farms often looks flawless, its nutritional value may not equal that of plants grown in more conventional ways.

One possible benefit of vertical farming is that it has the potential to provide people with fresher vegetables. A lot of modern vegetables are bland because they have been bred to be unnaturally large and to withstand long transportation chains, not for flavor or nutrition. Also, many vegetables, like tomatoes, are picked before they are ripe and then dosed with ethylene gas so that they will turn red off of the vine and still be edible by the time they arrive on a supermarket shelf (Dhall & Singh, 2013). This means that they have fewer nutrients and are less flavorful than they would otherwise be. However, all fruit and vegetables lose some of their nutritional value after harvest, so the sooner they're eaten, the more nutritious they are (Gil et al., 2006). Vertical farms are generally built close to large population centers with the intention of reducing the time between harvest and sale, meaning that vertically grown vegetables could be harvested and sold at peak ripeness. Growers could opt for varieties that are high in flavor and nutrition but less hardy than those that are designed to travel across the country or internationally since the time and distance between harvest and sale can be drastically reduced.

Because vertical farms maintain consistent growing conditions regardless of the weather outside, they are able to grow food year-round, and they are much less vulnerable to extreme weather events or changes in climate. This guarantees a steady flow of products for retailers and consumers as well as consistent income for growers. However, this delicate equilibrium is entirely dependent on the maintenance of their technology. Power outages, structural damage or deterioration, and even computer viruses could potentially wreak havoc in the controlled environments that vertical farms rely on. Of course, this is true of virtually all modern enterprises that rely on advanced technology for their day-to-day needs, but it is indicative of the level of rationalization inherent in vertical farming. In vertical farms, the unpredictability of nature is replaced by more controllable but socially dependent inputs like electricity and piped-in water. However, as most of the technology involved in vertical farming is new, there is still plenty of unpredictability. According to a representative from Square Roots, everything can go wrong does go wrong, from malfunctioning water pumps to LED light burnouts. He compares the technology to the early days of the internet, stressing that although it is currently fully functional, there are still a lot of kinks to work out.

One issue rarely mentioned by vertical farmers and their advocates is that vertical farms require substantially more energy to operate than conventional farms. When asked about the energy requirements at Aerofarms, the representative that I spoke to equivocated but admitted that their operation uses “a lot” of energy. The representative from Square Roots was more straightforward. Unlike Aerofarms, which is located in a large, abandoned industrial building, Square Roots’ farms are located inside shipping containers. Each container uses 100 kilowatts of energy daily, roughly equal to 60 televisions running nonstop for 24 hours a day. That vertical farming requires significant amounts of electricity should be rather obvious considering that systems designed to regulate light, temperature, water, humidity, and atmospheric composition all require energy to operate. Meanwhile, the sun naturally provides conventional farms with an endless supply of free energy. Plants grown indoors can require up to 18 hours of artificial light per day. This has both economic and environmental costs. Since most existing vertical farms are connected to the electrical grid, their electricity largely comes from the burning of fossil fuels. Estimates show that lettuce grown in vertical farms has a carbon footprint two to five times higher than lettuce grown in conventional fields (Al-Chalabi, 2015), and that one pound of vertically grown lettuce produces eight pounds of CO_2 (Albright, 2012), making vertical farming a much bigger contributor to greenhouse gas emissions than conventional farming.

Advocates of vertical farming counter this argument with the claim that vertical farms in urban areas can significantly reduce carbon emissions related to transportation. In this way, vertical farms have been able to capitalize on the “locavore” trend. Eating locally produced foods has the double benefit of financially supporting local communities and cutting down on greenhouse gas emissions that come from transporting food thousands of miles across the country or even across the globe. On their website, AeroFarms claims that they reduce transportation emissions by 98% compared to most farms that grow leafy greens, which are located in California’s Salinas Valley. While this is certainly admirable, it fails to acknowledge that transportation only makes up 4-6% of the agricultural sector’s total greenhouse gas footprint (Weber & Matthews, 2008; Wakeland et al., 2011). So, if production in a vertical farm is two to five times more energy intensive than on a conventional farm, but it only reduces transportation-related emissions by 4-6% (or less, realistically, since some transportation will still be necessary), the net increase in emissions is still considerable.

However, as noted above, most of the technology involved in vertical farming is relatively new. Improvements in LEDs and photovoltaic cells may make the energy demands of vertical farms less demanding and the carbon footprint of providing that energy less environmentally harmful in the future. Theoretically, with efficient enough solar cells, wind turbines, or other sources of renewable energy, a vertical farm could produce as much energy as it uses, making it energy-neutral overall. Although some energy-neutral buildings have been developed, they are generally not used for energy-intensive activities such as vegetable cultivation. Because of their high energy demands, truly energy-neutral vertical farms may be a long way off. For now, vertical farmers have to make use of the energy system we have, not the one that we hope for.

Similarly, some idealistic designs for future vertical farms include spaces for a wide variety of fruits and vegetables. A design in Despommier's book even includes an orchard on the seventh floor. Unfortunately, for now, these designs are wholly impractical. This brings us to probably the largest barrier to feeding urban populations with crops grown in vertical farms. So far, their output is limited to leafy greens. Specifically, they focus on greens and herbs that fetch high prices per pound like kale, arugula, watercress, and basil. Leafy greens consist of approximately 90% water, are fairly easy to grow, and they produce very little inedible material (roots, stems, husks, etc.). They are also extremely low in calories and make up a very small part of the average person's diet. In order for vertical farms to truly compete with conventional farms, they must be capable of growing a wider variety of fruits, vegetables, and grains. Grains like corn, wheat, and rice make up almost half of the average person's diet, so any plan to feed an urban population would have to include the cultivation of these staple crops. At the moment, it is possible to grow grains hydroponically, so they could be grown in vertical farms theoretically. However, for a variety of reasons, it is much more economical to grow them in traditional fields.

First, grains require more energy inputs than leafy greens. A gram of dry yield requires a fairly uniform amount of energy received from light in the form of photons, regardless of plant species. Wheat consists of approximately 11.5-21.5% water (Berbert & Stenning, 1996) while greens are over 90%. In short, this means that the dry weight of a given amount of wheat will be much higher than the dry weight of a leafy green, thus requiring more energy and more growing time. Additionally, there is the issue of storage. Because of their low water content, grains store well. They can be kept in silos, transported over long distances, and handled fairly roughly. They are much less sensitive to environmental factors after harvest than fresh fruits and vegetables, which bruise and decay easily. This makes them grains suited to current agricultural and distributional methods. In other words, because grains require a lot of energy to grow, and they store easily, it is not economically viable to grow them in vertical farms. This means that unless major biochemical or technological breakthroughs take place, it will remain infeasible to grow grains in vertical farms. At the moment, the only economically viable crops to grow in vertical farms are leafy greens with high water contents.

Vertical farming's main selling point is that it is more efficient than conventional farming. This certainly seems to be true with regard to water use. Currently, around 70% of freshwater used globally is applied to agriculture. While this drops to around 40% in developed countries because of increased efficiency in irrigation (OECD, 2016), agriculture remains a major source of water use. Some vertical farms use hydroponic systems, which may use anywhere between 30% and 90% less water than conventional farms, depending on the type of produce being cultivated (Treftz & Omaye, 2015; Barbosa et al., 2015). AeroFarms claims to be even more efficient, using 95%

less water than conventional farming through its use of an aeroponic mist that sprays the crops' roots with a solution of nutrients dissolved in water.

Proponents of vertical farms often cite their efficient use of space as another benefit over conventional farming. While it's true that, through stacking, vertical farms are capable of growing many times more plants per square foot, the economic benefits of this are debatable. Vertical farms are generally intended to be located in or near highly populated cities. The problem is that rent in highly populated cities is generally not affordable. Meanwhile, farmland is relatively cheap, especially in countries with large open spaces like the United States. For example, a 0.96-acre parcel of land in Newark with an abandoned industrial building on it similar to the site purchased by AeroFarms is currently available for $2.6 million on the commercial real estate website LoopNet. By comparison, the price of an acre of farmland in the U.S. costs on average around $3,000 (AgWeb, 2015). However, an acre of premium land in the Salinas Valley, where most of the country's leafy greens are commercially grown, can fetch up to $60,000 (CaASFMRA, 2016). Simply put, an acre of extremely fertile farmland in California is less than 1/40 the price of an acre of brownfield real estate in Newark. Furthermore, urban farmers often underestimate the enormous scale of conventional agriculture. Former wheat geneticist for the USDA and outspoken critic of vertical farming, Stan Cox, has calculated the amount of space that would be needed for vertical farms to replace all of the fields growing vegetables in America (not including potatoes). He found that it would take the floor space of 105,000 Empire State Buildings. And that would only grow America's vegetables, which use only use 1.6% of the country's total cultivated land (Cox, 2012).

For vertical farming to truly compete with conventional farming, despite the efficiency of stacking, it would require vast swaths of urban real estate. Of course, real estate only makes up a small part of the overall cost of operating an agricultural site. In addition to the ongoing costs of energy, inputs, and staff, vertical farms require significant amounts of capital upfront. To date, AeroFarms has raised over $100 million, including a $1 million grant from the Foundation for Food and Agriculture Research, $9 million in grants and tax breaks from the city of Newark and the state of New Jersey, and millions in private investment from international holding companies such as the Dubai-based firm Meraas and China’s GSR Ventures (Crunchbase, 2018). This massive startup cost means that building and operating a large-scale vertical farm is dependent on corporate buy-in, placing it out of the reach of the vast majority of independent farmers around the world.

Clearly, starting a vertical farm of this size is a long-term investment that cannot be expected to turn a profit for quite some time. Some companies may be willing to ride out a long period of non-profitability for the chance of securing substantial profits in the future, but many vertical farms - including PodPonics in Atlanta, FarmedHere in Chicago, and VertiCulture in New York City - have already succumbed to the forces of the market and shuttered their doors. It remains to be seen whether or not the newest crop of vertical farms can overcome the enormous hurdles associated with earning a profit through vertical farming.

It is certainly likely that vertical farms will continue to produce leafy greens and herbs for niche markets, as the novelty and sterility of plants grown without dirt in controlled environments are likely to remain selling points for some consumers. They may even, with technological advances, begin to profitably grow high-value fruits like strawberries and blueberries. However, in summary, the ability of vertical farms to feed millions of people remains untenable for several reasons. First, the types of crops that can realistically be grown in vertical farms are extremely limited, and the available plants tend to produce low-energy foods. You cannot feed the world on baby kale. Second, the energy requirements are staggering. Even an energy-neutral vertical farm may be considered a waste of resources, considering that crops are capable of receiving 100% of their energy from the natural environment. Unless a global cataclysmic event occurs or the effects of climate change become so drastic that conventional farming is no longer possible, mediating the growing process through solar panels and LED lights is unnecessary at best. Last, the amount of space required, even with significant stacking, is enormous. A warehouse filled with rows and rows of vegetables may look impressive, but even the largest vertical farms currently in existence only have growing areas of around one acre. By comparison, Iowa alone has 30,622,731 acres of farmland (ISDC, 2016).

3.2 Vertical Farming in the Global Corporate Food Regime

Based on all of the obstacles described above, it is probable that vertical farming's overall impact on the global corporate food system will be minimal, at least in the near future. Although the Internet is littered with articles proclaiming that vertical farms are the solution to all of humankind's problems, very few successful farms are actually operating. There are a handful of vertical farms in core countries like the United States, Belgium, and Japan, but their overall impact on the global food system is negligible. However, it could be argued that vertical farming's small global impact is a feature, not a bug. Vertical farming is often promoted as an alternative to the globalized food system that relies heavily on food shipped around the world. If the point is to provide fresh food for local communities, it is currently achieving its goal to some extent. For instance, greens grown by Aerofarms and Square Roots are available in and around New York, and Square Roots has plans to expand to several other cities in the United States. The goal is to feed communities within those cities, not to produce food for export. It's worth noting, though, that both companies serve the New York area, which can support an expensive, niche foodie product like vertically grown greens.

Peripheral countries, and indeed even most parts of core countries, cannot afford the food produced by today's vertical farms, whose retail prices are equal to that of the most expensive organically grown produce in the supermarket. In fact, it is not only most consumers who cannot afford it, but producers run into the same problems as they do with precision agriculture, only worse. The initial investment involved in starting a vertical farm is far too costly and unlikely to pay off for entrepreneurs in peripheral countries. Moreover, the same issues with infrastructure exist. Vertical farming requires reliable electricity, water, and internet. If any of these services are disrupted, the environment ceases to be controlled, crops fail, and growers lose money.

Another factor limiting the spread of vertical farming, even within core countries, is a lack of expertise in the field. Since the technologies involved in vertical farming are so new, there are very few people who are trained to operate and maintain them. Most of the employees in these operations are highly educated and experienced in working with advanced technologies. The list of job openings on Aerofarms' website reveals the kind of employees that are required to run this type of company. Of the twenty full-time jobs listed, ten are engineering positions, and three are positions for scientists. Some of the other jobs are less clear about what kind of experience they require, such as Quality Assurance Supervisor, which requires a "4-year degree in a relevant study" (2018b), but it's not a stretch to expect that that position will also be filled by a scientist or engineer. In all, eighteen of the twenty jobs listed require a university degree in a STEM or business track. The two remaining jobs, Production Line Worker and Night Shift Sanitation Worker are the only unskilled positions available (and, interestingly, the only positions with "worker" in the title). If this is an accurate representation of the kind of employees that a vertical farm startup needs, it skews heavily toward highly skilled workers with university degrees. In most peripheral countries, it may be difficult to find enough qualified workers to run a company like Aerofarms. Furthermore, there may be few people with valuable university degrees who are willing to take a risk on a technology that has not yet proven itself profitable.

The caliber of employees at Aerofarms also has a major effect on the company's bottom line, as its payroll is mostly filled with highly skilled workers near a major metropolitan area. This does not bode well for advocates of vertical farming who envision a future where vertical farms located in every major city are capable of providing enough food to more or less feed the local urban population. In addition to the issue of space mentioned above, the existence of that many vertical farms would require an incredible number of highly skilled workers who would essentially be replacing the lower skilled farmers whose urban markets they have usurped.

This trend toward skilled workers may become even more pronounced with the development of advanced automation. Already, the Japanese agrotech company, Spread Co. Ltd., is developing a fully automated vertical farm in Kizugawa, Japan. This farm uses robotic arms to plant and harvest lettuce and is expected to reduce the cost of labor by 50%. The workers who will no longer be needed in an automated farm are almost certainly those doing unskilled work such as planting, watering, and harvesting the crops. However, highly skilled workers will still be necessary to develop and maintain the robots. Spread Co. Ltd. claims that its vertical farms can be used anywhere in the world, and although this may be true in theory, vertical farms simply cannot work in most parts of the world due to the previously discussed issues of logistics and profitability.

Although advocates of vertical farming claim that it could solve problems ranging from hunger to climate change, it is worth considering whether or not a future in which vertical farms play a major role in feeding urban populations is actually desirable. If vertical farming does eventually become feasible through developments in renewable energy and automation, what kind of effects would that have on the global food system? First, it would most likely put food production even more firmly into the hands of large corporations. The companies involved in vertical farming today are relatively small (although Aerofarms' $100 million in seed money is certainly not trivial). However, Google was once a small startup too. Companies like Aerofarms and Square Roots see themselves as trailblazers on the cutting edge of an industry that will be widespread and extremely profitable in the future. And maybe they're right. If so, these small startup companies may grow to rival tech giants like Google and Amazon.

Already, large corporations play a major role in the agricultural sector in core countries. Although nine out of ten American farms are technically family farms, that does not mean that the system is designed to benefit small farmers. As previously mentioned, large, corporate farms, despite being small in number, produce much of the food and earn most of the profits in the United States. Moreover, most of the profits in the food industry are not earned by farmers. The real winners in the corporate food regime are agrotech companies, meat companies, and major food retailers (Hauter, 2012). For example, Monsanto's net income (after deducting all expenses and taxes) was around $2.3 billion in 2016 (Monsanto, 2017). Agrotech companies earn huge profits for themselves and their stockholders by selling farmers virtually all of their inputs, including seeds, fertilizers, and pesticides.

A corporate food regime in which vertical farming plays a significant part would likely be even more dominated by corporate interests, as a food's entire lifecycle from seed to supermarket shelf would be controlled by corporations. Although proponents of vertical farms often emphasize the "community" aspect of locally grown food, the reality is that these companies' hierarchical corporate structures do not allow for much community engagement. In fact, since their entire *modus operandi* is to micromanage every aspect of the growing process, the general public necessarily cannot participate. Vertical farms are not like community gardens where neighbors can get together to pull weeds and shovel compost. The precise nature of the project requires that only trained workers are allowed to come into contact with the plants. Aerofarms doesn't even offer public tours due to safety concerns.

Certainly, turning over full control of our food system to corporations is not likely to lead to a more engaged citizenry. Put another way, it would be a blow against "food sovereignty." Originators of the concept of food sovereignty, the farmers' organization La Vía Campesina defines food sovereignty as,

> [T]he right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems. It puts those who produce, distribute and consume food at the heart of food systems and policies rather than the demands of markets and corporations (Rosset, 2003).

Although corporations are now legally defined as people, it can't be seriously argued that a corporate-run food system reflects the people's "right to define their own food and agricultural systems." In fact, considering the scale and scope of corporate farming in America, it is arguably already be the case that Americans do not have true food sovereignty. However, giving large corporations even more power would surely reduce food sovereignty even further.

Infamously, agribusiness companies like Monsanto have received criticism for patenting seeds. Vertical farms are now also patenting aspects of their production process. For instance, AeroFarms mists its plants with a proprietary nozzle that was designed to prevent clogging. Through technological dominance, some vertical farming companies may be able to gain monopolies in the agricultural sector, effectively eliminating their competition. This is likely to give these companies outsized powers to lobby and dictate agricultural and environmental policy, further reducing democratic control over our food systems.

3.3 Vertical Farming and Ideology

Vertical farming shares some ideological characteristics with precision agriculture while diverging in other important ways. First, vertical farming is also a strictly market-based endeavor. It unquestioningly presumes a capitalist future in which vertical farming supersedes conventional agriculture because of its superior profitability. Square Roots, in particular, heavily promotes the fact that it is a business, and that businesses are honorable endeavors that reward values like ingenuity and hard work. The purpose statement on their website reads: “Square Roots’ mission is to empower entrepreneurial leaders through real food” (2018). Interestingly, according to this mission statement, the primary beneficiaries of this project are not the customers who will eat their food but the entrepreneurs involved in producing it. Of course, this is true to an extent in any business in which the goal is the turn a profit. There may be a social mission attached to the company, but profitability is always the primary objective. It is a little jarring, though, that Square Roots so openly admits its entrepreneurial self-interest.

Second, vertical farming companies address issues of sustainability but engage with them much more directly than precision agriculture firms do. While precision agriculture focuses first and foremost on producing large amounts of food to literally feed the world, vertical farming’s appeal is not that it produces great quantities of food but that it produces high quality food that is good for the planet. Although both Aerofarms and Square Roots gesture toward a quotidian notion of simply feeding people real food, the details of their operations and their marketing campaigns reveal that their goals are loftier and involve environmental considerations like reduced water usage.

Last, vertical farming also shares with precision agriculture the ideology of rationalization, taken to the extreme. In fact, vertical farming is the ultimate logical conclusion to Cartesian reductionism and absolute rationalization, in which every single imaginable component of the growing process is accounted for. Vertical farming rationalizes its control over nature to the point that nature is only ancillary to the process of growing food. Utilizing the vernacular of Silicon Valley-style tech startups, Square Roots' co-founder and CEO remarked in an interview that, "We literally hack the fire hydrant" (Cahlan, 2017), referring to their efficient use of water. In this view, every aspect of production is something to be "hacked" or improved upon. Nature itself is too slow and unpredictable, but the rational faculties of humankind can improve upon it.

In many ways, vertical farms are more akin to factories than conventional farms. Like factories, they are in the business of continually producing virtually identical commodities. Aerofarms seeks not only to create a stalk of healthy watercress. It seeks to create the Platonic ideal of a stalk of watercress - free of any aesthetic flaws, optimally nutritious, embodying the plant's essential flavor, and exactly identical to every other stalk of watercress that the company produces. In this way, it creates the perfect industrial agricultural commodity. Like other industrially-produced foodstuffs, a major goal of any large food producing enterprise is uniformity. Uniformity increases the ease with which commodities are exchanged. When trading in large quantities, it eliminates the need to calculate losses due to deformed or otherwise inedible products. It also makes packaging and shipping easier, since, in theory, one could calculate the exact number of stalks of watercress that go into an 8 oz. box, and one could accurately anticipate the weight of a crate of 100 boxes. All of this simplifies the logistical challenges that firms must handle when dealing with non-uniform products.

Although uniform products are desirable for their role in streamlining the exchange process, that alone is not reason enough to warrant the use of the sophisticated and expensive technologies utilized by Aerofarms and Square Roots. The logistical benefits gained by uniformity would be meaningless if there were insufficient demand for the product in question. Broadly speaking, consumers prefer foods that match their aesthetic expectations (US EPA, 1992). They want straight, bright orange carrots and flawlessly red tomatoes. This puts extreme pressure on growers to produce uniform and aesthetically pleasing foods because retailers and consumers will reject fruit and vegetables that do not meet their standards. According to a food distributor in an interview with the Guardian, “It’s all about blemish-free produce... What happens in our business today is that it is either perfect, or it gets rejected. It is perfect to them, or they turn it down. And then you are stuck” (Goldenberg, 2016).

Today, only four food retailers are responsible for half of all grocery sales in America (Hauter, 2012). Because of monopolization in the food retail sector, growers often have no alternative but to comply with the standards imposed by retailers. Otherwise, they will not have consistent buyers for their agricultural products. Thus, it makes economic sense to produce the most standardized and aesthetically pleasing fruit and vegetables possible. In this way, vertical farms are adhering to the requirements established by the market.

Similarly, in recent years, consumers have become increasingly concerned over the origins of their food and the conditions in which it is produced (Moser et al., 2011). More and more, consumers demand food that is “organic,” “free trade,” and “local,” ushering in what Harriet Friedmann calls a kind of “ecological or ‘green’ capitalism” (2005, p. 229). This ideological shift toward a more conscious consumerism is, at once, the result of over a century of anti-capitalist pro-labor and environmental organizations seeking to raise the public’s consciousness around the exploitative nature of capitalist production, and the cooptation of that that same moral crusade by capitalist enterprises as a form of branding (whether cynically or earnestly). Slavoj Žižek calls this “cultural capitalism” (2009, p. 52) and argues that purchasing goods with positive ethical attachments brings pleasure and meaning to our lives and, we believe, it tells us what kind of person we really are. We are not only consuming, we are "showing our capacity for care and our global awareness, participating in a collective project" (p. 54). And fortunately for us, it only costs a few extra cents to take part in this philanthropic endeavor.

In this vein, one of Square Roots' more unique claims is that their model allows consumers to know their farmers. In fact, this isn't just a clever marketing line since customers who sign up for a weekly delivery plan actually get their greens delivered to their door by one of Square Roots' "farmers." This injunction to know your farmer is part of a larger discourse that glorifies local small business owners, promotes relationships within the community and, at least indirectly, disparages globalization. Whether this truly reflects Square Roots' values or not is debatable. At this point in their development as a business, they have not yet expanded outside of New York, and their reach is small enough that they can still have their farmers feasibly make deliveries by hand. In any case, this rhetoric works as a marketing ploy in a society where most people do not feel a deep connection to their food, or if they do feel a connection, it is merely a connection to the cultural signifiers associated with certain foods.

In Marxian terms, food in the modern world is characterized by commodity fetishism, in which food is simply a commodity to be bought and sold while the social relations that go into food production are largely obscured. The value of a product on a supermarket shelf is viewed as inherent to the product itself in relation to other commodities, when in reality value only exists as a social relation between people (Marx, 2011; Ollman, 1977). For farmers, growing food is not much different from growing cotton or other non-consumable crops. Either way, it's ultimately about producing an exchangeable commodity that has value. Meanwhile, consumers do not generally know where their food comes from and are mostly ignorant of the processes involved in getting food onto their plate (Vinter, 2013). This is amplified in the case of international trade, where consumers may not even know which country their food comes from, making the social relations embedded into its production virtually unknowable. Although they certainly do not think of it in these terms, the Square Roots model effectively reduces the level of commodity fetishism involved in procuring healthy food. Square Roots is fairly forthcoming about their growing process, their business interests, and their distribution system, giving consumers a greater feeling of community unity and trust in their food. Similarly, Patricia Allen and Martin Kovach argue that the increasing prevalence of organic food has improved the public's awareness of environmental and social issues related to food production and contributed to the defetishization of sustainable agricultural products (2000). One could argue that vertical farming takes the process of defetishization one step further.

Aerofarms makes similar claims, with their website proclaiming that they are "Building healthier communities" and "Farming locally. Globally" (2018a). The focus on community, local food, and Square Roots' call to "know your farmer" indirectly serve as condemnations of the globalized food system and the separation of city-dwellers from the countryside where their food is produced. Marx also criticized the unnatural division between city and country, leading to the concept of "metabolic rift," which Marx himself did not coin but which later thinkers in the Marxian tradition identified. Metabolic rift refers to the result of the unequal distribution of the population under capitalism, with crowded city centers relying on sparsely populated rural areas for all of their food and raw materials for clothing and shelter. This disrupts the natural recycling of organic matter and leads to degradation of the soil. The "rift," according to JB Foster, consists of the gap between the "metabolic interaction between man and the earth" (1999, p. 380), which deepens man's alienation from his species-being. In the *Communist Manifesto*, Marx and Engels laid out some measures to deal with this rift, namely, "the improvement of the soil generally in accordance with a common plan," and "gradual abolition of all the distinction between town and country by a more equable distribution of the populace over the country" (1978, p. 490). Although the solutions offered by vertical farmers are wildly different than those envisioned by Marx and Engels in the mid-19th century, they both endeavor to address similar issues of environmental degradation and feelings of disconnection from the production of food. The differences in their solutions, however, reveal significant ideological divergences. For Marx and Engels, metabolic rift is the inevitable result of capitalist production, which drives rural populations off of their land and creates a city-dwelling proletarian class to produce the goods necessary for the endless flow of capital required by the current economic system. Their solution calls for methodical central planning. For entrepreneurial vertical farmers, though, the only solution to the excesses of capitalism is more capitalism. From this perspective, consumers know what's best for them and will choose to purchase products that align with their values. In the case of vertical farming, these values include environmental sustainability (as emphasized through statistics on minimal water usage and reduced food miles), locavorism, and health consciousness. It is interesting that these capitalist enterprises recognize and are trying to address some of the same problems outlined by Marx 150 years ago. Despite espousing an explicitly pro-market ideology, there does seem to be an understanding that certain aspects of capitalist development have led to a harmful disconnect between food growers and consumers as well as environmental degradation. In reimagining the ways in which food can be grown, these companies are also reimagining relationships between producers and consumers.

Similarly, these companies are reimagining what it means to eat healthily. Since vertical farms are only capable of profitably growing leafy greens at the moment, it makes sense to take advantage of this fact and emphasize the healthiness of the food that they produce. However, they can go even further, claiming that *their* leafy greens are particularly healthy because of the conditions in which they are grown. Square Roots claims that through the manipulation of light, temperature, and atmosphere, they can produce plants that are not only optimally nutritious (although, as noted earlier, that claim is questionable) but optimally nutritious for specific, individual consumers. The representative I spoke to said that they could create different environments for the plants to promote higher levels of certain nutrients based on the needs of individual consumers. Clearly, this is an absurd idea, as it implies a much more fine-grained understanding of nutrition than we currently have. The idea that a change in atmospheric CO_2 could change the amount of certain nutrients in leafy greens enough to have a measurable effect on a person's health is far-fetched. However, it reveals that personalization is another salient ideological trend in the neoliberal fantasy imagined by vertical farmers. While uniformity is a defining feature of conventional commodities, commodities that are customizable and personalizable can transcend the category of basic commodities to something truly unique and desirable. It is no coincidence that Burger King's famous motto, "Have it your way," originated in 1974, at the beginning of what is commonly considered the era of neoliberalism. A unique feature of neoliberalism, according to David Harvey, is its focus on individual freedoms. However, as one of neoliberalism's other central tenets is an absolute faith in markets, the primary way in which those individual freedoms manifest themselves is through personal consumer choices. He writes:

> Neoliberalism ... had to be backed up by a practical strategy that emphasized the liberty of consumer choice, not only with respect to particular products but also with respect to lifestyles, modes of expression, and a wide range of cultural practices. Neoliberalization required both politically and economically the construction of a neoliberal market-based populist culture of differentiated consumerism and individual libertarianism (2005, p. 42).

The culture of differentiated consumerism is particularly visible in the ways in which people eat in the 21st century. Consumer food choices are designed to signal to others concerns about health, the environment, workers rights, animal rights, money, status, and support of small businesses, to name just a few examples. Personalization sends another strong message such as, “I am a unique individual whose personal needs cannot be met by mass-produced consumer goods.” This is rare with regard to food products, which are generally fairly standardized. In this way, Square Roots may have identified a particularly clever way of advertising its product that is especially suitable for the neoliberal era.

Vertical farming is the culmination of a number of colliding economic and ideological forces. First, it represents the pinnacle of rationalization, which controls every facet of production and replaces human labor with automated fixed capital wherever possible. Second, it produces a uniquely standardized product, turning an agricultural product, which has historically taken on varied shapes, sizes, and colors, into a perfectly uniform and fungible commodity. Last, it taps into the demand for food that is sustainably and locally produced. It does this through a number of claims that promote vertically farmed food as more ecologically friendly than conventionally grown crops. These claims offer a vision of the global food system that is driven by the traditional profit-maximizing incentives of capitalism plus a unique conscious consumerism that characterizes the “green capitalism” movement. Similarly, a focus on local, community-based food promotes a traditional, pre-industrial relationship between growers and consumers that acts as the antithesis to modern, industrial agriculture. Finally, the promise of personalized vertically grown designer foods perfectly encapsulates the dream of neoliberal techno-futurist capitalists to create a world in which the simple act of eating your vegetables is not only an expression of your preference as a consumer but more importantly an expression of your true self.

CHAPTER 4: CONCLUSION

On one hand, precision agriculture and vertical farming have many technical features in common, such as a focus on automation, the Internet of Things, and the use of big data. They also stem from similar ideologies that emphasize the twin logics of the market and rationalization. On the other hand, the global reach of precision agriculture greatly exceeds that of vertical farming. By and large, precision agriculture is the domain of massive agribusiness corporations, many of which have existed in one form or another for decades. By comparison, most vertical farm companies are relatively small startups. Even Aerofarms, which has received over $100 million from investors, is still tiny compared to companies like Dow, Monsanto, and John Deere, which take in billions of dollars each year wield control over the precision agriculture industry. While the impact of vertical farming is currently negligible and its future viability as a widespread method of feeding people is questionable, precision agriculture has already changed the face of modern farming. As the adoption of precision agriculture technologies grows, it will continue to transform the social and economic fabric of rural areas across the globe.

Private sector investment in agricultural R&D has outpaced public investment over the last twenty to thirty years, and corporate consolidation has led to a situation in which six multinationals control the vast majority of the world's agricultural technology development (Piesse & Thirtle, 2010). The narrowing of competition among firms similarly limits the scope of the technologies being developed, with companies concentrating R&D spending on technologies that have already proven to be the most profitable. Technologies that deviate from the current trends in data collection and automation taking place on enormous, input-intensive monocropped fields are not generally pursued by agribusiness giants. This means that truly alternative visions for sustainable agriculture are likely to remain unexplored and underfunded.

The most highly anticipated innovations in both precision agriculture and vertical farming are in the field of robotics. The market research firm, WinterGreen Research Inc., reports that the market for agricultural robotics in 2013 was $817 million. By 2016, it had more than doubled to $1.7 billion, and by 2023, they predict it will reach $27.1 billion (WinterGreen, 2014; WinterGreen, 2017). It may be nice to imagine a near-future in which all of the backbreaking drudgery of farm work is done by robots, leaving people to enjoy plenty of fresh, healthy foods while pursuing other, less physically demanding work. Unfortunately, as multinational corporations take full command of the global food chain, public demands are replaced with private interests. The International Panel of Experts on Sustainable Food Systems predicts that the full seizure of the food system by an ever-shrinking cabal of agribusiness firms will lead to a number of negative consequences. These include weakened commitments to sustainability, heightened public health risks, exploitative practices related to data-collection, increased labor abuse, and fraud (IPES Food, 2017).

A report by the United Nations with the disconcerting title *Wake Up Before It Is Too Late* similarly expresses deep concern over the industrial agricultural system that is propped up by the corporate food regime. The report argues that sustainability can best be achieved through small-scale, organic farming with a focus on agroecology, and that:

> The merging of knowledge with technology and science to create innovations that address the broad range of issues in a systemic manner, in contrast to the reductionist approach that promotes biotech and genetic engineering industries, needs to be strongly promoted through public sector investment (UN CTAD, 2013, p. 175).

Private interests that are motivated by the drive to maximize profit - not a desire to solve the diverse set of problems facing the planet in the 21st century - are unlikely to provide sustainable solutions that meet the needs of the world’s seven billion people.

Numerous scholars and think tanks have proposed alternatives to the current food system (IPES Food, 2016; Kloppenburg Jr., 1991; Shiva, 2016), but scholars do not, for the most part, determine the course of global economic affairs. With little institutional power to affect the corporate food regime outside of local sustainable projects, the current hyper-capitalist model that treats food like any other commodity is unlikely to change. Although innovations in agricultural technology present unique opportunities to provide everyone on earth with sufficient quantities of healthy food while minimizing environmental degradation, the realization of that goal depends on the just and equitable application of those technologies.

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