Digitizing Agriculture: Sustainable Development Discourse of Big Data Agriculture in California and India

A capstone summary presented by
Blake Slattengren

Lewis & Clark College
In partial fulfillment for the degree of
Bachelor of Arts in Environmental Studies

Spring 2018

Abstract

This research paper is concerned with the relationship between technology adoption and sustainable development through examining impacts of big data agriculture in California and India. Big data is an emerging set of technologies that collect and analyze large data sets for more efficient farming and effective decision making. California and India are two locations in radically different sustainable development contexts that are both employing big data agriculture as driven by technology startups, making them a useful point of comparison. In order to see the kinds of change coming about from these ag data companies, this paper uses statistical analysis to look at who are the companies driving these technologies and uses content and discourse analysis to analyze the sustainable development discourse expressed by these companies.

This paper finds that ag data shows potential positive impacts on economic growth, food systems infrastructure, food security in India, and water availability in California. On the other side, ag data has negative impacts on displacing labor and increasing inequalities, both in access to technology and data security. In general, these companies are ingrained in the culture of modern technology startups, meaning that companies are fairly homogeneous in thought and personnel and they are facing similar sustainable development problems as many other early stage technology companies. I propose further research and a set of recommendations to increase the positive sustainable development impacts and minimize the negative.

Acknowledgements

I would like to thank all the professors who helped me throughout this past year, with special regards to my capstone advisor, Jim Proctor. I also could not have completed this without the advice and support of all my peers in Senior Seminar with me. Finally, I would like to thank all the people working for ag data companies who responded to my calls and emails and taught me about the industry.

For a public report that presents this research in a visual and accessible manner, visit: http://ds.lclark.edu/bslattengren/capstone

Background

In what ways does new technology adoption further or inhibit sustainable development?

Guided by the above question, this research paper takes aims to provide insight into the tumultuous relationship between technology and sustainable development. This takes on added relevance when discussing artificial intelligence, 3D printing, advanced synthetic biology, and other technologies that comprise of a new wave technological development, dubbed the fourth industrial revolution. Proposed by economist and founder of the World Economic Forum Klaus Schwab, this revolution promises radical changes across continents that will redefine fundamental relationships between people, technology, and environment (Schwab 2017). One particular technological advancement that is already making huge changes in business operations is big data, a technology that collects and analyzes vast amounts of information in order to improve efficiency and decision making (Cukier and Mayer-Schoenberger 2013).

How exactly these new technologies will change the world is a highly contentious and largely unknown topic (Schwab 2017). Nevertheless, a number of scholars, business people, and governments present these technologies as ways to meet sustainable development goals (King 2017). Sustainable development is a concept that suggests ways for nations to develop in a way that acknowledges the connections between human rights, economic growth, and environmental changes (Redclift 2005). The current global standard for sustainable development is the United Nations Sustainable Development Goals (SDGs), as outlined in the 2015 report, *Transforming Our World* (Transforming 2015). While certainly admirable in their aspirations, these goals are criticized for being broad, vague, wildly optimistic, and not universally practical for every country (Holden et al. 2017). Still, these goals provide a great framework for understanding our modern world and demonstrate generally agreed upon markers of positive societal development.

The UN's sustainable development goals are also quite ambitious and will be difficult to meet. New technology, however, is one proven way to meet goals through driving economic growth (Sachs 2015). Beyond economic growth, many new and emerging technologies also promise sustainable development through higher efficiencies and clean energy development. Yet, while the benefits of technology are huge, drawbacks are sure to accompany any new technology (Sheth 2017). For example, the steam engine kicked off the first industrial revolution to huge economic development and increases in general health and quality of life, but it came with new problems such as workers rights and the mass production of greenhouse gases directly leading to climate change (Sachs 2015). Technology helps solve problems outlined in the SDGs, but also creates new problems along the way.

With the fourth industrial revolution on its way, it follows to question how new and emerging technologies may help nations meet the UN's lofty sustainable development goals and what sort of drawbacks may result. As governments, businesses, or engineers, we have the ability, or perhaps even responsibility, to control new technology adoption in a manner that maximizes the positive sustainable development effects while minimizing the negative effects.

Agriculture is a dynamic industry where sustainable development and new technology adoption have a long history together. This is especially evident during the green revolution, a technological revolution throughout the 20th century that allowed agriculture around the globe to meet the needs of a growing population with widespread use of high-yield crops, synthetic fertilizers, advanced irrigation systems, and motorized vehicles (Evenson and Gollin 2003). While the green revolution brought huge benefits with an increase in global food security and a decrease in hunger, these technologies were not without controversy and drawbacks (Hart 2003). Take, for instance, the use of the dangerous pesticide DDT in America in the 1950s or the ongoing debates around genetically modified foods of the late 20th century. These technologies also greatly shifted who was farming and the role of the farmer. In general, fewer and fewer people were becoming farmers as farmers were able to manage more cropland easier than ever before. The farm itself became more of an industrial model, with farms vertically integrating the entire food production process and becoming orders of magnitude larger than before (Hart 2003). While there has been significant backlash against the industrial farm, overall, this is a global trend that continues today.

Empirically driven farming is also nothing new, as for more than a century, farming has been data driven through tracking property and capital use and resources such as the Farmer's Almanac (Bronson and Knezevic 2016). Even precision agriculture techniques such as more advanced input tracking and mapping of farms have been around since the 1980s (Shanwad et al. 2004). Big data, then, is the latest in a long line of technologies that make farming more efficient than ever before. Currently popular for making business and investment decisions, especially for technology companies, big data is a concept that is now moving into other industries, including agriculture (Sonka 2014). Big data is made possible by a number of related technologies such as digital storage, cloud computing, and internet of things (IoT) devices that allow for the collection and storage of exponentially more information than ever before (Sonka 2014). Big data represents distinct, but related, technologies to precision agriculture technologies because of the sheer amount of data and data processing available as well as the digitization of variables that have never existed before (Cukier and Mayer-Schoenberger 2013).

For the purposes of this research, I am defining two primary categories of big data technologies: data capture and data analytics. Data capture consists of any technology that generates farm-specific data. Within data capture, IoT technologies are the most common. IoT is any set of physical, internet-connected devices that turn physical information into digital. For agriculture, IoT consists primarily of a variety of sensors that take the form of physical sensors in the soil, farm machinery, or on plants themselves and sensors that track water, pesticide, or fertilizer use, hyperlocal weather conditions, and plant health (Kamilaris et al. 2017). The second set of data capture technologies are spatial imaging technologies including GPS and aerial imaging technology, such as unmanned aerial vehicles, more commonly known as drones. Many spatial imaging companies are not exclusive to ag data, but operate in multiple industries. Once collected, raw data is difficult to use without some sort of analytics software. Data analytics technologies can take agricultural data collected by IoT and spatial imaging and identify farm-specific trends and useful statistics and recommendations. Software consists of a variety of services that interpret and compare data to let farmers know when and where to use water and pesticides, buy inputs, sell outputs, and generally allow farmers to more efficiently manage their land (Kamilaris et al. 2017). Often packaged concurrently with data analytics technology are additional data technologies and services such as data storage, management, transfer, and marketplace analysis.

Situated Context

While people and businesses all around the world are developing ag data technologies, startups have taken the charge in pushing these technologies on the market. California, in particular, with its significant investment in industrial agriculture and entrepreneurship, has acted as a hub for ag data technology. California, of all US states, is seeing some of the largest growth in agriculture, especially industrial agriculture, ideal for big data adoption (Hart 2003). In addition, the US has more AgTech investment than any other country and California has more than double the investment of any other state (AgTech 2017). This made California an ideal location to analyze big data agriculture.

California is also interesting in that agriculture, while important for the state and takes up much of the land, represents a small part of the state's GDP at 2% and an even smaller percentage of the state's labor at 1% (California 2016). Some of the biggest problems for California agriculture are a lack of available freshwater, decreasing migrant laborers, and making a reliable profit due to variable weather patterns and changes in pricing (Mohan 2017). These three problems correspond to SDGs 6 and 8. However, California exists in a development context that prioritizes a very specific set of SDGs. In order to gain a greater perspective of the global impacts of ag data, it is useful to compare California to a country in a radically different development context, such as India.

India is one of the world's largest agricultural producers with agriculture taking up 17% of the country's GDP and about 50% of all employment (India 2017). India is a particularly interesting context because of the significant AgTech investment present, albeit more in companies focused on distribution and making efficiencies in the supply chain (AgFunder 2018). Still, there are a number of Ag Data companies that have received notable investments in the past several years. Indian Ag Data companies, however, face quite different sustainable development challenges with India having significantly less development than the US. Some of the biggest problems facing Indian agriculture are surrounding food security and lack of reliable distribution infrastructure, corresponding to SDGs 2 and 9 (Sheth 2017).

In both California and India, similar actors drive big data development and adoption, as depicted in the actor-network map below.

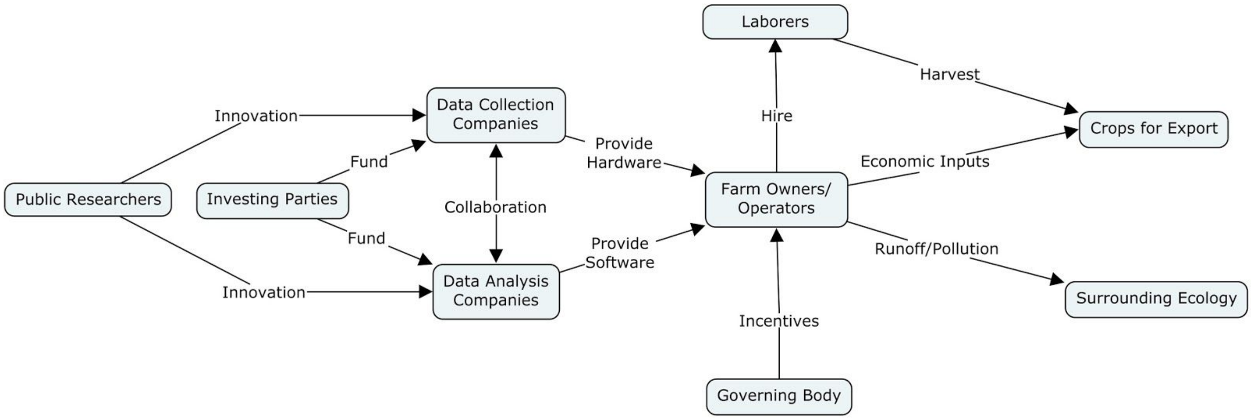

Figure 1: Actor-Network Map depicting key relationships in ag data development and adoption

While the general relationships between actors are consistent across contexts, the power of different actors and importance of various relationships varies greatly by specific location. For example, incentives provided by governing bodies change greatly by country and the impacts to the surrounding ecology change greatly from farm to farm. In addition, some of these actors are not necessarily distinct entities in every context, such as farm owners and laborers or data collection and analysis companies. In California, actors with greater influence include the governing body, United States Department of Agriculture (USDA), and public institutions, University of California schools and the Defence Advanced Research Agency (DARPA) (Monhan 2017; Cukier and Mayer-Schonenberger 2013). In India, farm owners, laborers, and crops all exhibit greater influence (Chaturvedi et al. 2016). The difference in sustainable development goals, food systems infrastructure, and influential actors suggest that a comparison of California and India will lead to a greater understanding of the benefits and drawbacks of ag data technology in different contexts.

Research

To what extent are sustainable development goals addressed by big data agriculture companies in California and India?

Methodology

This question above sets out to analyze how big data in agriculture is treated as a way to meet sustainable development goals and the resulting implications. Similar studies have interviewed farmers or conducted ethnography (Carolan 2016; Crane 2014), but I hope to look at this question through the startups who are driving change. These companies advertise various sustainable development values, but the impacts of large-scale adoption of big data agriculture is still quite speculative. Through analysis of discourse presented by big data companies, core values are demonstrated and present a picture of sustainable development envisioned by the companies pushing the technology.

First, data was collected concerning the main companies working in ag data: how big are the companies in investment and employment, who are on the management teams, and how long have these companies been in business. With these variables and some statistical analysis, general trends were made apparent and essential background information on the key actors in ag data was provided.

Next, content analysis of the company websites was conducted, coding key phrases to UN Sustainable Development Goals. Theses goals correspond to various expressions made by companies, but there is one slight distinction by separating the goal of "decent work and economic growth" into two separate goals that address the farm labor conditions and increased profits, respectively, as these represent distinct, but related, outcomes. This analysis will consists of both of a numeric count of sustainable development goals as well as an analysis of the specific words or phrases used. This will demonstrate the discourse promoted by companies and show how they see themselves as contributing to various goals while also highlighting the goals that are not addressed.

As there is some subjectivity in this coding process, I will walk through an example coding of the Wexus Technologies website (https://wexusapp.com/), a data analytics company based in San Francisco. First, I scroll through the homepage looking for key terms that evoke UN Sustainable Development Goals. One of the first that comes up is, "Reduce Waste: Save money off your energy bill via features such as rate analysis, pump efficiency tracking, irrigation cost calculator & more". The phrase "Reduce Waste" corresponds to the responsible production and consumption goal, so I would save the entire phrase and count Wexus as contributing to that sustainable development goal. Beyond the home page, I also look at the "solution" page as solutions tend to evoke various sustainable development goals. In these two pages, other key phrases that come out include "stay on top of your… water usage" corresponding to clean water and sanitation, "integrate renewable energy" corresponding to affordable and clean energy, "eliminating manual data entry" corresponding to decent work , and "Save money off your energy bill" corresponding to economic growth. Other main webpages include, "Pricing", "Team", "Blog", "FAQ", and "Contact Us". However, I do not bother coding these pages as they discuss the specifics of the technology and company, which I am not interested in at this stage, as it is not directly inciting sustainable development.

Finally, narrative analysis of The Climate Corporation and CropIn Technologies, two of the largest ag data companies based out of California and India, respectively, will provide a more nuanced look into how ag data companies position themselves as contributing to certain sustainable development goals. By targeting customer pains, the story that these companies tell reveals key problems faced by customers and how these technologies are positioned to solve them. These companies also both reveal certain statistics for what their technology has actually accomplished to attempt validation of the goals they advertise.

Results and Discussion

Figures 2 and 3: Location of California and India-based ag data companies. Small markers represent one company while the large marker represents four

First, while California and India are very different locations, there are a number of unexpected similarities and differences between their ag data markets. For example, while California has significantly more ag data companies, both locations find the majority of their companies located in areas with strong tech and startup culture, San Francisco and Bengaluru. It is also evident that companies are not necessarily located close to areas with significant agricultural land use.

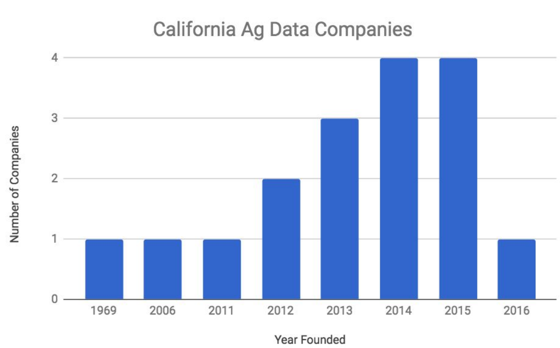

Figure 4: Percentage of California-based companies founded in the above years

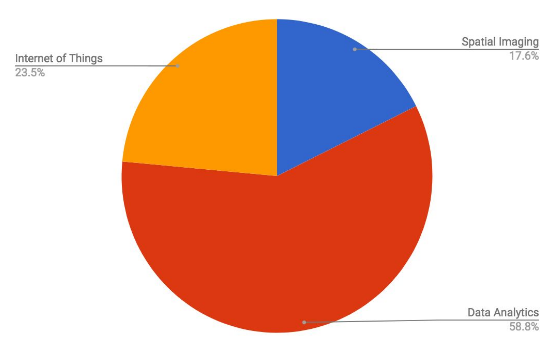

Figure 5: Percentage of California-based ag data companies by technology

Just looking at California companies, we see a number of interesting trends. Something that immediately stood out was that these companies are, for the most part, very much ingrained in modern startup culture. The majority of the ag data companies were founded in the past five years in the San Francisco Bay area by white males. For example, of the 17 companies, only two were founded before 2012 and only three have women on their leadership teams. Very few companies expressed any actual farming background. This lack of diversity means that most of these companies have very similar outlooks and values leading to a lack of new, innovative ideas and companies that do not necessarily represent the interests of farmers.

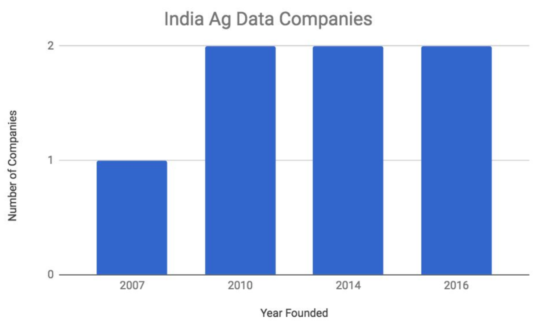

Figure 6: Percentage of India ag data companies founded in the above years

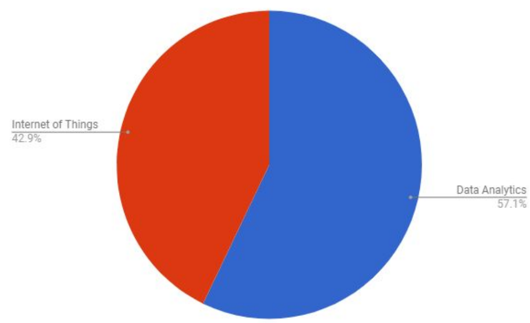

Figure 7: Percentage of India-based ag data companies by technology

In India, a similar story can be told. Surprisingly, more Indian companies predated 2012 with three of the seven companies analyzed, but the majority was still from the past five years. Although companies were represented from across the country, three of the seven were from Bengaluru, the startup capital of India. Furthermore, none of the companies had women on their leadership teams. This similar lack of diversity could also be a problem for finding innovative solutions.

Sustainable Development Goals	% of Companies Expressing Value
Economic Growth	88
Responsible Production and Consumption	41
Clean Water and Sanitation	35
Decent Work	35
Industry, Innovation, and Infrastructure	35
Good Health and Wellbeing	18
Reduced Inequalities	18
Zero Hunger	12
Affordable and Clean Energy	6
Sustainable Cities and Communities	6
Life On Land	6

Figure 8: Table of SDGs expresses by California-based ag data companies

Looking closer at California companies, some of the most commonly expressed values include economic growth (with 88% of companies expressing the value), responsible production and consumption (41%), clean water and sanitation, decent work, and industry, innovation, and infrastructure (all at 35%). The most commonly used words include “data”, “energy”, and “irrigation”. Together, this all paints a picture of companies that are focused on technology advances that help farmers profit and produce food responsibly. Notably, a number of California’s sustainable development problems are represented. For example, it makes sense a significant amount of companies focused on using less water and needing less workers.

Sustainable Development Goals	% of Companies Expressing Value
Economic Growth	100
Industry, Innovation, and Infrastructure	57
Zero Hunger	43
Decent Work	43
Reduced Inequalities	43
Clean Water and Sanitation	29
Life On Land	29
Good Health and Wellbeing	14
Affordable and Clean Energy	14
Life Below Water	14
Partnerships for the Goals	14

Figure 9: Table of SDGs expressed by India-based ag data companies

India also shared some similar expressed values. The top values were economic growth (with 100% of companies expressing this value), industry, innovation, and infrastructure (57%), zero hunger, decent work, and reduced inequalities (all at 43%). On average, Indian companies expressed more values as well, with an average of four values per company as compared to three values per company in California. Commonly used words include “farmers”, “solutions”, and “time”. All in all, Indian companies were much more concerned about sustainable development in general and focused on telling a story about farmers problems that are solved with big data rather than focusing on the technology itself. Like California, Indian companies talked more about problems for Indian farmers, such as food security and reducing inequalities.

Next, through a deeper look into Climate Corporation and CropIn Technology, a number of relevant narratives become clear. One of the first that becomes obvious is Climate Corp establishing an emotional connection with the technology with the question posed: “If your fields could talk, what would they say?”. This is a common strategy that speaks to a common fear of technology and change, but this is perhaps becoming more prevalent with the new, more powerful than ever technologies of the fourth industrial revolution (Sheth 2017). Companies need to convince their customers that technology adoption is a positive force and not something to be feared. CropIn also appeals to this sensibility through case studies providing examples of actual people and farms who are benefitting from their technology.

Another apparent narrative is the concept of sustainability conflated with efficiency. Both company's promise sustainability, but this is treated primarily as a promise of efficiency. This is made obvious when CropIn seems to say the same thing three ways when promising efficiency, productivity, and sustainability or when they promise “smarter” solutions by “maximizing per acre value”. Of all the SDGs that could be used to discuss sustainability, it is primarily goal 8, economic growth and decent work, that is evident in company advertising. Climate Corp also demonstrates this when discussing the benefits of their technology being “get all your data in one place, “uncover valuable field insights”, and “optimize your inputs”.

With the headline, “Bringing Silicon Valley to the Farm”, Climate Corp also brings out a narrative about ag data companies being tech companies applied to farming rather than farming companies using tech. This is also evident in the headquarter locations of ag data companies, such as Silicon Valley, reflecting cities driven by technology and entrepreneurship, not agriculture. This also overlaps with a narrative of big data taking agriculture to the “future of farming”, where as most modern agriculture is considered primitive. This can be a problem as it treats new technology as inherently better for simply being new and innovation without concern to the implications. In addition, this thinking can lead to farmers being left out of the conversation as the researchers and entrepreneurs behind the technology are prioritized (Crane 2014).

Finally, this narrative analysis also makes evident the difficulty in validation of sustainable development impacts. Climate Corp validates their sustainable development goals through the GRI report of their parent company, Monsanto. Monsanto has been completing internal sustainability reports since before their acquisition of Climate Corp, so the money and infrastructure was already in place for Climate Corp. CropIn, on the other hand, does not complete any sort of sustainability report, but they still project validity through showing the reach and use of their products. However, for both Climate Corp and CropIn, projected validity do not match with the SDGs advertised through their website. Overall, there are a number of shared narratives between the two companies, resulting in more similarities than differences in projected values.

Implications

Big data is certainly only becoming more of a mainstream practice in agriculture and will continue to influence sustainable development goals. In an ideal world, big data will make agriculture run as efficiently as possible while minimizing inputs and food waste and maximizing farmer profits. However, actual adoption of big data technologies are significantly more complication, and the three biggest concerns for big data in agriculture, as raised by literature, are decreased labor and increased inequalities, including data security (SDGs 8 and 10) (Carbonell 2016; Kamilaris et al. 2017).

As the case with many technologies associated with an industrial revolution, ag data has the power to replace laborers (Schwab 2017). Yet, this seems to only be a huge problem if adoption of the technology is rapid, as agricultural labor is already decreasing globally. For example, many companies discussed replacing laborer, but it was often spun as a positive. For example, Mavrx, a company from San Francisco, advertised, “Scale your labor force without adding boots on the ground”. On one hand, advertising scaling up your farm is a way to get around the fact that laborers could be replaced by these technologies. On the other hand, California does have a decreasing population of migrant and low-wage laborers, so this can understandably be a positive. Other companies are more obvious in their labor-replacing intentions. Take, for instance, Avanijal Agri Automation, a Bengaluru based company, who writes, “Due to mass urbanization, getting an agriculture labour is big challenge. Even if farmer manages to get the labour, many a times they do not manage irrigation well due to ignorance and/or negligence”. This also explores a trend of decreasing agricultural labor in India while bringing up the inefficiencies of human labor as compared to automation.

Relatedly, big data threatens not only the laborers themselves, but rural cultures as well. From Michael Carolan’s paper *Publicising Food: Big Data, Precision Agriculture, and Co-Experimental Techniques of Addition*, one farmer, Paul, shares, “Yields are great but I worry about how technologies like this distract from those other things that we’re growing, biodiversity, trust, strong communities. If we all start evaluating each other based on what we’re hauling to the elevator every fall, that’s not the culture that attracted me to farming” (Carolan 2016). The changing culture of farming could also serve to disincentivize farmers and result in the displacement of laborers. While a small handful of companies emphasize their relationships with rural communities, this discussion is almost entirely absent from the discourse of ag data companies.

Ag data could also contribute to significant inequities between farmers that can afford the best data technologies and those who can not. San Diego based Slantrange acknowledges this as they advertise, “The cost of data collection, processing, and information delivery must be drastically reduced so that the benefits of these new types of information can accrue even to smallest farmers in the most remote regions of the world”. Slantrange attempts to take on these international inequalities by providing their services at a bargain. Bengaluru based CropIn Technologies claims, “Meet today’s agri-needs while strengthening resources for the future by creating a healthy environment, economic profitability, and social & economic equity for all. Empowering the agri in the agri-ecosystem by enabling businesses to benefit from actionable insights while empowering farmers through advisory & alerts”. CropIn gets into how their technology empowers farmers and increases profits, but avoids how it might affect those who cannot afford their technology. Though some companies are addressing this issue, inequalities will serve to further drive division between large, industrial farms and small, more traditional farms.

The divide between farmers and other actors is also a cause for concern. Agronomist UK Shanwad writes, “ [The adoption of big data technologies] will be a stupendous task and a threatening challenge to space and agricultural scientists alike who are currently remotely placed from the ground truth of Indian farming. However, the speeds of these transformations depend very much on the level of commitment of politicians, scientists, bureaucrats and technocrats at whose mercy the farmer really is!” (Shanwad et al. 2004). Equitable access to ag data technologies will be hugely important to the successful adoption of the technology.

Another equity-based concern raised by literature was the security of farmer data (Bronson and Knezevic 2016). Many farmers were concerned about their data getting in the hands of agribusinesses who could take advantage of the data, but with a lack of research, it is uncertain to what extent data security presents as a perceived and real risk for farmers (Carolan 2016). This is summarized by Douglas Hackney, president of a data management business, who explains “For a big data company, what is a farmer? It’s an account number… for a farmer, if their data falls into the wrong hands, it’s an existential threat” (Carbonell 2016). Several farmers have also expressed these concerns. Take, for example, the farmer Eric, who explains his scepticism with big data: “Thanks to these big data companies what’s to keep someone from viewing a farmer as just a number that grows next to another number? And what if those numbers get out? What if one of my landlords got their hands on that data and they see that another neighbour might be yielding more, or they’re able to see trends – yields on their land going down, yields on neighbour’s land going up?” (Carolan 2016). While a few companies in both California and India promoted their secure networks, data security was largely absent from the discourse of companies as compared the importance of the issue for farmers and did not present itself as a key driver currently for ag data. Outside the sphere of start-ups, there are also advocates for responsible and secure data use, such as the Open Ag Data Alliance (Wolfert et al. 2017). Data security will likely become more important as big data farming becomes more widely adopted.

Overall, big data is a tool that can help countries work towards sustainable development goals, such as economic growth, food security, and water availability. Yet, developed countries may be better served by the technology currently due to increased technology infrastructure and having less agricultural labor. The effectiveness of big data is also highly dependent on farm specific variables such as agriculture department policies, food system infrastructure, and farm specific ecology, weather, size, and labor. As a result, while there are sustainable development goals that will benefit from ag data, the specific benefits of ag data change from country to country and from farm to farm. Also, labor and equity are areas where big data may actively work against sustainable development goals. While it is unclear to what extent these negative effects undermine the benefits provided by ag data, it is clear that businesses, governments, and researchers can all take steps to promote responsible technology adoption as described below.

In addition, these are not problems exclusive to ag data. Labor displacement and increasing inequalities are sustainable development problems that plague technology adoption in general and are predicted to be major drawbacks of the Fourth Industrial Revolution (Schwab 2017). So, broadly speaking, in what ways does new technology adoption further or inhibit sustainable development? I think this research illuminates the fact that this question depends greatly on the technology and context of adoption. In general, however, trends exist toward increased economic growth, responsible production, and improved infrastructure as well as increased labor displacement and inequalities.

In order to promote the responsible adoption of ag data technologies the following steps can be taken. First, before any practical policy recommendations can be issued, further research should be done to address how companies advertised sustainable development values translate to actually meeting stated goals. This would ground sustainable development discourse with indicators that prove effectiveness of ag data. Different locations should conduct this analysis in order to see the effectiveness in various contexts.

Governments should consider promoting responsible technology adoption by properly incentivizing ag data adoption. Incentive programs for data technologies already exist, such as the Precision Farming Incentive under the the Environmental Quality Incentive Program for the United States Department of Agriculture. This incentive program is great for decreasing pesticide use with GPS-enabled machinery. However, I would recommend expanding this program to include additional technologies, especially data analytics technologies, with additional goals such as decreased water use. I would also recommend increasing incentives to smaller farms with less access to ag data technology and creating the ability for disincentives if labor displacement becomes a larger problem. With these adjustments, this incentive program can address the problems raised in this report.

For ag data companies, labor and equity are concerns that threaten the long-term longevity of their businesses and should be actively engaged with. Most importantly for companies would be ensuring that ag data is accessible to farms of different size, location, and profitability. Programs such as Climate Corporation's FarmRise Mobile Farm Care app are a great example of ways to engage a greater number of farmers with ag data. In addition, diversity of company location and personnel should be increased in order to bring new perspectives and ideas to ag data.

For farmers, ag data represents a way to save money and run their farm more efficiently, but adoption of the technology should be carefully considered depending on the specifics of both the farm and the technology in order to ensure effective use of the technology. I also encourage increased support and growth of farmers rights and ag data adoption advocacy organizations, such as AgGateway and Open Ag Data Alliance, who successes so far. These two organizations are based in the United States, so creation of additional organizations focused in different locations globally is critical as well.

Finally, for the researchers working in big data, technology adoption is an ethical question and should be considered carefully. In addition to research on verifying the sustainable development impacts of ag data in various locations, further studies can look at the sustainable development impacts for big data in other industries, such as energy, forestry, or education. Big data is emerging as an important technology in a many contexts and the methodological framework here can be applied to any industry with big data startups. Beyond big data, this framework can also be used for any number of technologies that are coming in the Fourth Industrial Revolution where technology adoption is driven by startups. Research in these different contexts will further explore the relationship between technology adoption and sustainable development and show trends in the sustainable development values that will be benefitted or hindered by emerging technologies.

Bibliography

"AgFunder AgriFood Tech Investing Report - 2017." 2018. AgFunder.

"AgTech Funding Report: Year In Review 2016." 2017. AgFunder.

Alexovich, Ariel. 2017. "SDG Report: Pace of Progress Must Accelerate." *United Nations Sustainable Development* (blog). July 17, 2017.

Bronson, Kelly, and Irena Knezevic. 2016. "Big Data in Food and Agriculture." *Big Data & Society* 3 (1): 2053951716648174. https://doi.org/10.1177/2053951716648174.

"California - May 2016 OES State Occupational Employment and Wage Estimates." 2016. Bureau of Labor Statistics. May 2016.

Carbonell, Isabelle M. 2016. "The Ethics of Big Data in Big Agriculture." *Internet Policy Review* 5 (1). https://doi.org/10.14763/2016.1.405.

Carolan, Michael. 2016. "Publicising Food: Big Data, Precision Agriculture, and Co-Experimental Techniques of Addition." *Sociologia Ruralis*, January, n/a-n/a. https://doi.org/10.1111/soru.12120.

Chaturvedi, Sachin, Krishna Ravi Srinivas, and Amit Kumar. 2016. "Agriculture Technology Choices and the Responsible Research and Innovation (RRI) Framework: Emerging Experiences from China and India." *Asian Biotechnology & Development Review* 18 (1): 93–111.

Crane, Todd A. 2014. "Bringing Science and Technology Studies into Agricultural Anthropology: Technology Development as Cultural Encounter between Farmers and Researchers." *Culture, Agriculture, Food and Environment* 36 (1): 45–55. https://doi.org/10.1111/cuag.12028.

Cukier, Kenneth, and Viktor Mayer-Schoenberger. 2013. "The Rise of Big Data: How It's Changing the Way We Think about the World." *Foreign Affairs* 92: 28. https://doi.org/10.2469/dig.v43.n4.65.

Evenson, R. E., and D. Gollin. 2003. "Assessing the Impact of the Green Revolution, 1960 to 2000." *Science* 300 (5620): 758–62. https://doi.org/10.1126/science.1078710.

Hart, John Fraser. 2003. *The Changing Scale of American Agriculture*. University of Virginia Press.

Higgins, Vaughan, Melanie Bryant, Andrea Howell, and Jane Battersby. 2017. "Ordering Adoption: Materiality, Knowledge and Farmer Engagement with Precision Agriculture Technologies." *Journal of Rural Studies* 55 (October): 193–202. https://doi.org/10.1016/j.jrurstud.2017.08.011.

Holden, Erling, Kristin Linnerud, and David Banister. 2017. "The Imperatives of Sustainable Development." *Sustainable Development* 25 (3): 213–26. https://doi.org/10.1002/sd.1647.

"India Country Profile." 2017. UN Data. 2017. http://data.un.org/CountryProfile.aspx?crName=INDIA.

Kamilaris, Andreas, Andreas Kartakoullis, and Francesc Prenafeta Boldú. 2017. "A Review on the Practice of Big Data Analysis in Agriculture." *Computers and Electronics in Agriculture* 143 (October). https://doi.org/10.1016/j.compag.2017.09.037.

King, Anthony. 2017. "Technology: The Future of Agriculture." *Nature* 544 (7651): S21–23. https://doi.org/10.1038/544S21a.

Long, Emmaline A., Quirine M. Ketterings, David Russell, Francoise Vermeylen, and Stephen DeGloria. 2016. "Assessment of Yield Monitoring Equipment for Dry Matter and Yield of Corn Silage and Alfalfa/Grass." *Precision Agriculture* 17 (5): 546–63. https://doi.org/10.1007/s11119-016-9436-y.

Mohan, Geoffrey. 2017. "As California's Labor Shortage Grows, Farmers Race to Replace Workers with Robots." *Los Angeles Times*, July 21, 2017.

"Precision Agriculture in Rice Production." 2014. Australia: Rural Industries Research and Development Corporation.

Redclift, Michael. 2005. "Sustainable Development (1987-2005): An Oxymoron Comes of Age." *Sustainable Development* 13 (4): 212–27. https://doi.org/10.1002/sd.281.

Sachs, Jeffrey D. 2015. *The Age of Sustainable Development*. Columbia University Press.

Schwab, Klaus. 2017. *The Fourth Industrial Revolution*. Crown Publishing Group.

Shanwad, UK, VC Patil, and Honne Gowda. 2004. "Precision Farming: Dreams and Realities for Indian Agriculture." In .

Sheth, Parul R. 2017. "Sustainable Development and the Role of Science and Technology." *Current Science (00113891)* 112 (8): 1616–17.

Sonka, Steve. 2014. "Big Data and the Ag Sector: More than Lots of Numbers." *International Food and Agribusiness Management Review* 17 (1).

"Transforming Our World: The 2030 Agenda for Sustainable Development." 2015. United Nations.

Wolfert, Sjaak, Lan Ge, Cor Verdouw, and Marc-Jeroen Bogaardt. 2017. "Big Data in Smart Farming – A Review." *Agricultural Systems* 153 (Supplement C): 69–80. https://doi.org/10.1016/j.agsy.2017.01.023.