Lewis & Clark College
Environmental Studies Capstone
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Digitizing Agriculture

A Critical Review of Sustainable Development Discourse of Big Data Agriculture in California and India

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Executive Summary

This report 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 report 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 report 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

Blake Slattengren is an Environmental Studies major at Lewis & Clark College graduating as part of the Class of 2018.

For a full scholarly summary including further background and additional discussion visit: http://ds.lclark.edu/bslattengren/capstone

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Background

What is Big Data?

Big data refers to modern technologies that allow for the collection, storage, and analysis of vast amounts of information. Technologies such as digital storage, cloud computing, and internet of things (IoT) devices allow for the collection and storage of exponentially more information than ever before.[1] Of particular importance, IoT technologies are web-connected devices that can turn physical information into digital, making them useful for generating data.[2] Once collected, modern analytics software can identify trends and useful statistics.
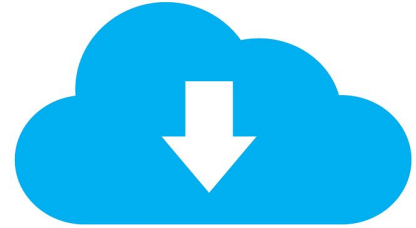
A familiar example of big data and IoT is a smartwatch, such as a FitBit. A smartwatch is an IoT device as it takes physical information, like one's heart rate throughout the day, and turns this information into data. The activity of one's heart now has a digital representation, but a smartwatch records information constantly and, on its own, there is too much data to be particularly useful. Analytics software, then, becomes critical to identify trends and give health advice to the user. However, big data is not limited to the tech industry. Big data allows for informed, efficient decision making and, as a result, is used in companies across every sector.[3]

Agricultural Uses

In agriculture, big data is gaining popularity as a way to make business decisions around land management, water and fertilizer use, and crop pricing.[4] Also known as precision agriculture, big data allows farmers to better manage large farms and make efficient use of inputs.

It is easy to see the appeal of data technology for farmers. Ideally, the technology minimizes inputs and maximizes farmer profits.[3]

The table to the right breaks down major categories of data technologies used by farmers.

Primary categories of big data technologies used in agriculture:

Data Capture: Data generating technologies. Most fall into the following two categories:

> **Internet of Things:** Physical sensors or devices that generate data. Examples include sensors in soil, on plants, or in irrigation or fertilization systems

> **Spatial Imaging:** Aerial images of cropland that generate data. Includes drone and geospatial imaging companies. Often work in multiple industries.

Data Analytics: Technology that analyzes data collected from third party sources for efficient decision making. May include additional services such as data storage, transfer, transformation, and market analysis.

Modern Agriculture

Agriculture is an industry where sustainable development and new technology adoption have a long and controversial history together.[5] 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.[6] With these technologies, in general, fewer and fewer people were becoming farmers as farmers were able to manage more cropland than ever before, a global trend that continues today.[6] Big data, then, is the latest in a long line of technologies that make farming more efficient than ever before.
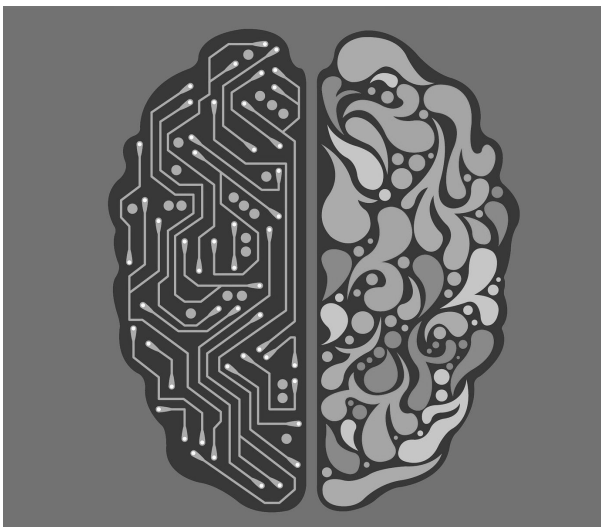
In 2017,

$673 Million

was invested, globally, in Ag Data companies.[7]

The Fourth Industrial Revolution

Proposed by economist and founder of the World Economic Forum Klaus Schwab, the Fourth Industrial Revolution consists of a number of modern, breakthrough technologies comprising a new wave of technological development including as artificial intelligence, robotics, 3D printing, and advanced synthetic biology.[8] Schwab suggests that these technologies will create radical changes across continents that will redefine fundamental relationships between people, business, technology, and environment.[8] Big data, along with IoT, is one such technology that is essential to the fourth industrial revolution. Already making large changes in business operations, the influence of big data is only expected to grow as other fourth industrial revolution technologies become more powerful.[3]

Sustainable Development

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.[9] In the discourse surrounding the benefits of ag data, sustainable development language is unavoidable, making it a great framework for discussing the impacts of big data agriculture. The current global standard for sustainable development is the United Nations Sustainable Development Goals (SDGs), as outlined in the 2015 report, *Transforming Our World*.[10] The 17 goals identified by the UN, listed below, cover a great range of topics from eliminating poverty to halting biodiversity loss.

While certainly admirable in their aspirations, these goals are criticized for being broad, vague, wildly optimistic, and not universally practical for every country.[11] 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 it will be difficult to meet the targets set out for 2030. Current progress must be accelerated to meet these lofty goals.[12] New technology, however, is one proven way to meet sustainable development goals primarily through driving economic growth.[13] Beyond economic growth, many new and emerging technologies also promise sustainable development through increasing efficiency and clean energy development. But while the benefits of technology can be huge, drawbacks are sure to accompany any new technology as well.[13] 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. Technology can help solve problems outlined in the SDGs, but will likely create new problems along the way.

Ag Data Companies

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 (See Appendix 1 for actor-network map of related relationships).[3] The US and California, in particular, with its significant investment in industrial agriculture and entrepreneurship, has acted as a hub for ag data technology.[7]

There is also significant AgTech investment in India, albeit more in companies focused on distribution and supply chain efficiency.[7] Still, there are a number of Ag Data companies that have received notable investments in the past several years. A comparison of these two locations will demonstrate a greater understanding of the potential sustainable development impacts of ag data.

Global Investment: Number of Deals per Country
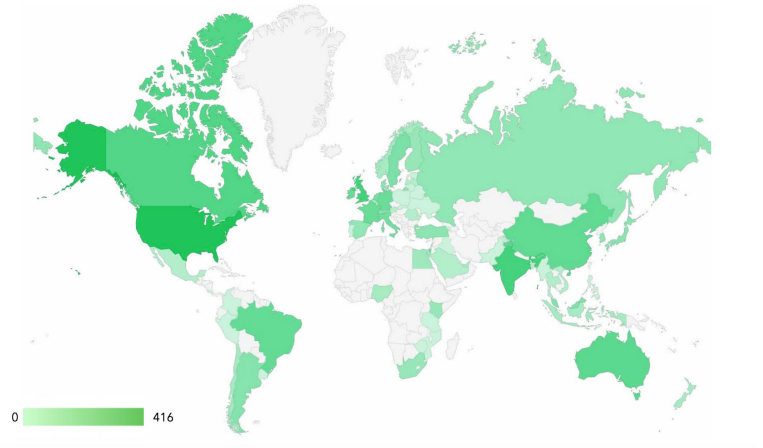
Figure 1: Global AgTech investment per country in 2017. Graphic taken from 2018 AgFunder Report.[7]

California-based Companies
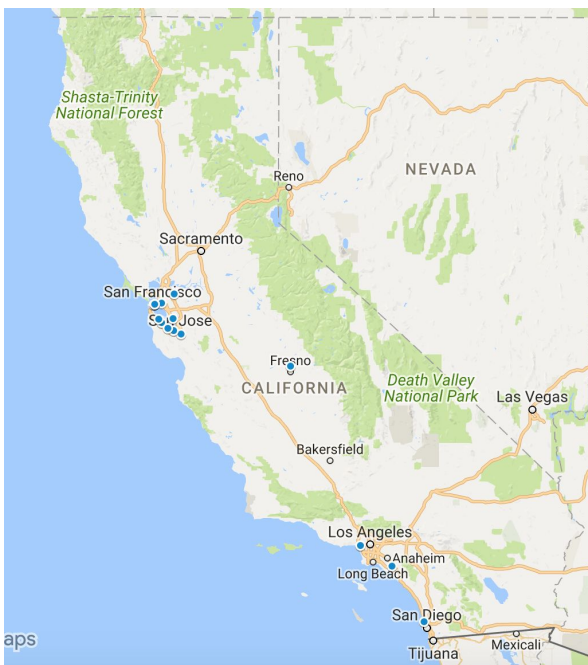
Figure 2: Map of California-based ag data companies

Refer to Appendix 2 for how these graphics were created as well as full research methodology
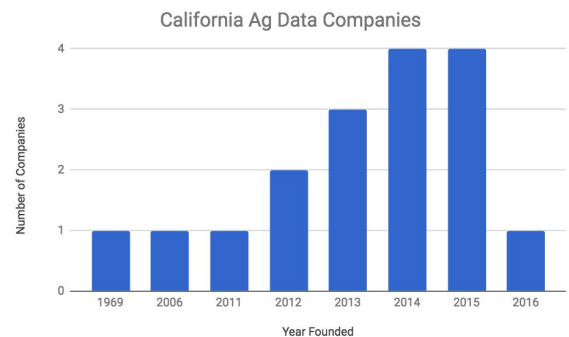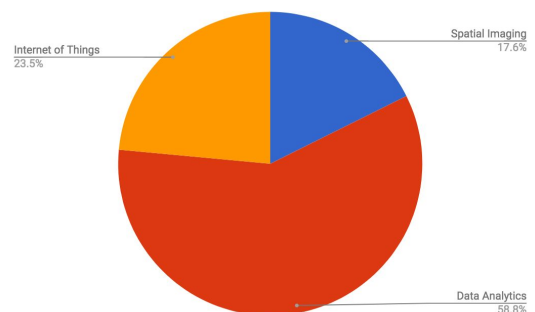

Figure 3: Percentage of California ag data companies founded in the above years

Figure 4: Percentage of California ag data companies by technology

India-based Companies

Figure 5: Location of India-based ag data companies. Small markers represent one company while the large marker represents four.
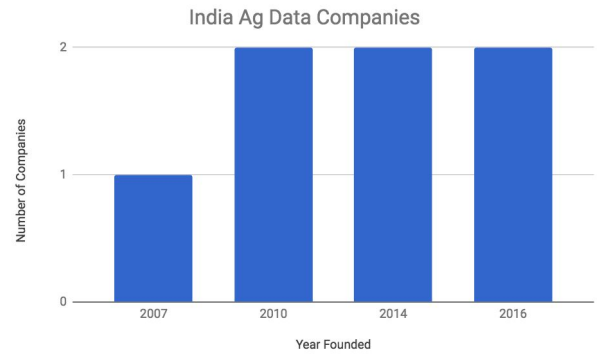

Figure 6: Percentage of India ag data companies founded in the above years
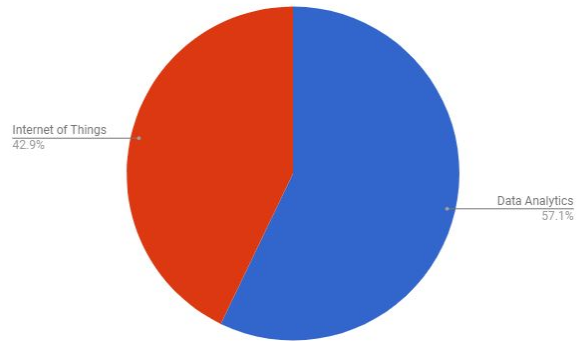

Figure 7: Percentage of India ag data companies by technology

Comparison of Locations

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.

There is also significant difference in the kinds of ag data companies in each location. Surprisingly, India has a much higher ratio of ag data companies founded before 2011. This is the result of a number of companies using technology to help farm productivity who have recently adopted more advanced data analytics technologies. This suggests that, despite a lack of companies, the companies that do exist have been successful and see significant opportunity for ag data in India.
Overall, however, ag data is a very recent market trend with new startups continuing to innovate and create better sensors and analytics tools. Especially in California, there is also evidence of high rates of company acquisitions and bankruptcies. In addition, most companies in both California and India focus primarily on data analytics technologies. Yet, California also has a number of companies with spatial imaging technologies, which is not yet seen in India.

Generally, it is clear that these companies are very much ingrained in modern startup culture. As a part of this, there is a significant lack of diversity for companies in both locations with only three California companies having women on their leadership teams and none from India. This lack of diversity means that most of these companies tend to 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.

Content Analysis

California

Of surveyed companies, the following SDGs were advertised the most frequently. Below shows the percent of companies expressing each value along with an example value statement:

"Farmers using AgMRI earn a better return on their investment, with lower input costs, improved yields, and a deeper understanding in real-time of what's going on in their fields." - IntellinAir
"Scale your labor force without adding boots on the ground" - Mavrx

88% - Economic Growth
35% - Decent Work
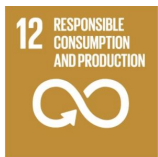
"With the rise of herbicide-tolerant weeds, there are fewer and fewer effective solutions. Farmers around the world need a new way to address the weed control challenge. Over-relying on a handful of broadcast-spray chemicals fuels the evolution of herbicide tolerance." - Blue River Technologies

41% - Responsible Consumption and Production

"Tule provides site-specific irrigation recommendations based on your production goals, so you can efficiently make more accurate irrigation decisions about when and how much to irrigate." - Tule

35% - Clean Water and Sanitation

"We go beyond pretty images and NDVI. We are dedicated entrepreneurs, engineers, data scientists and agronomists bringing technology to agriculture to pragmatically change the world" - Vinsight

35% - Industry, Innovation and Infrastructure

- On average, a company advertised 3 SDGs, with spatial imaging companies expressing the most values and data analytics expressing the least.

- No correlation between number of values advertised and size of company or diversity of team

- In figure 8, notice words primarily concerned with technology and efficiency.

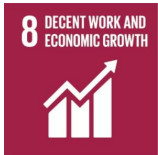Figure 8: Most common words in the value expressions of California-based companies

India

Of surveyed companies, the following SDGs were advertised the most frequently. Below shows the percent of companies expressing each value along with an example value statement:

100% - Economic Growth
42% - Decent Work

"Real time intelligence to multiply real farm economics by 2x" - Airwood

"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. " - Avanijal

57% - Industry, Innovation and Infrastructure

"The fourth revolution in farming is here. We stabilize supply and increase farm productivity by 2x by tracking over 50 farm variable and employing next generation data science & domain techniques… The Fourth Industrial Revolution is here and it's A.I.-Powered" - Airwood

42% - Zero Hunger

"The world population is expected to cross the 10 billion mark by the middle of the century and its combined impact with urbanization and the rise of middle class is bound to create a higher demand of healthy, fairly produced, and sustainable food which would require the current produce to double by that time." - CropIn

42% - Reduced Inequalities

"MATT has been designed to operate in low-resource conditions similar to those found in Indian mandis. It has a low power requirement and can function offline as well." - Nebulaa

Figure 9: Most common words in the value expressions of India-based companies

- On average, a company advertised 4 SDGs, one value more than California-based companies.

- No correlation between number of values advertised and size of company or diversity of team.

- In figure 9, notice words primarily concerned with people and farming.

Discussion

California, with its significant investment in industrial agriculture and entrepreneurship, has acted as a hub for ag data technology. This made California an ideal location to analyze big data agriculture. Some of the biggest problems for California agriculture are a lack of available freshwater, decreasing migrant laborers, and making a reliable profit due to changing weather patterns and variable pricing.[6] These three problems correspond to SDGs 6 and 8 and were, unsurprisingly, well represented in the results.

Some of the most commonly expressed values for these companies 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 in value expressions 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 and it follows that a significant number of companies are focused on using less water and needing less workers.

In contrast, Indian Ag Data companies, 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, both represented in the results as well.[14]

India shared a number of similar expressed values with California. 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 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. Indian-based companies also talked more about problems for Indian farmers, such as food security and industrial food infrastructure.

Narrative Analysis
The Climate Corporation

CLIMATE FIELDVIEW
IF YOUR FIELDS COULD TALK, WHAT WOULD THEY SAY?

GET YOUR DATA IN ONE PLACE

UNCOVER VALUABLE FIELD INSIGHTS

OPTIMIZE YOUR INPUTS

The first words that appear on the homepage. Anthropomorphizes fields to establish emotional connection for a technology. Suggests that big data represents responsible production (SDG 12).
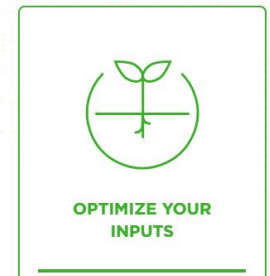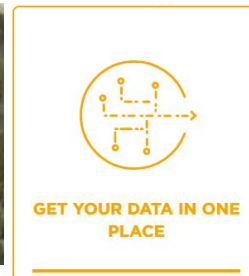
The three advertised features of Climate Corp's Fieldview service: Ease of use, risk prevention, and input efficiency (SDG 8, 12).

Bringing Silicon Valley to the Farm

A blog article dated January 4, 2018. Discusses ag's digital revolution and how Climate Corp is pushing the envelope in context of other tech industries (SDG 9).

CLIMATE FIELD VIEW prime
Simple tools for timely decision making
Free
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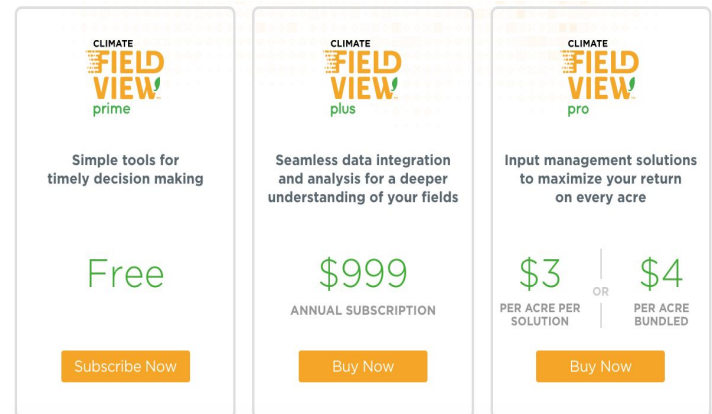$999
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$3 PER ACRE PER SOLUTION OR $4 PER ACRE BUNDLED
Buy Now

Fieldview's tiered pricing structure. Includes a free version andt a $999 annual subscription to access most features.

GRI Sustainability Report:

7 AFFORDABLE AND CLEAN ENERGY

8 DECENT WORK AND ECONOMIC GROWTH

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

16 PEACE, JUSTICE AND STRONG INSTITUTIONS
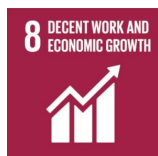
The proceeding are SDGs specifically most commonly referred to in Monsanto's (Climate Corp's parent company) GRI report when discussing Climate Corp. Note that SDGs 8 and 12 are evident in their advertising while 7 and 16 are not.

FarmRise is a free app targeted to Indian farmers. The app directly addresses some equity concerns as it is free and accessible to farmers. It also acts as a way to slowly introduce Climate Corp's ag data products to growing market of Africa and Asia. This app is not advertised at all on Climate Corp's website.

FARMRISE™ MOBILE FARM CARE
Smallholder farmers are often challenged with rural isolation and limited agronomic resources. FarmRise Mobile Farm Care is a platform from The Climate Corporation that delivers **free information and advice to smallholder farmers** to help them achieve better harvests.

90%
of farmers globally are smallholders

70%
have access to cell phones

CropIn Technology

MAXIMIZING PER ACRE VALUE.

Constant Innovation and Disruption to provide smarter agri solutions

Watch Now

INCREASE EFFICIENCY.
SCALE PRODUCTIVITY.
STRENGTHEN SUSTAINABILITY.

We're transforming businesses through intelligence and insight.

The first words that appear on the homepage. A clear emphasis on efficiency, profit, and innovation (SDG 8, 9)

Efficiency, productivity, and sustainability as the three benefits CropIn provides. Demonstrates promise of good things, but does not clarify the difference between these and their relationship to SDGs.

smart**farm**   smart**risk**   m**warehouse**   smart**sales**
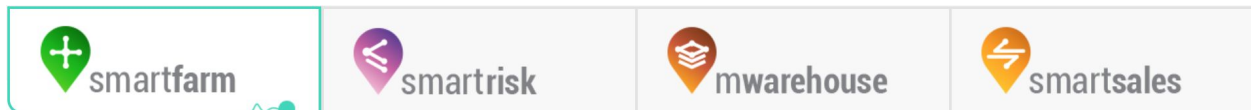
CropIn offers four distinct products focusing, from left to right, on general farm management, identifying risks (SDG 9), supply chain traceability, and market analysis (SDG 12).

Three case studies:

USING TECHNOLOGY FOR RURAL UPLIFTMENT & WOMEN EMPOWERMENT

DIGITIZING FARM FOR TRACEABILITY, COMPLIANCE AND OUTPUT PREDICTABILITY

USING TECHNOLOGY FOR BUSINESS GROWTH & PREVENTING CHILD LABOR

In the first case study, CropIn technologies are used to uplift rural farmers, a majority women, through farm data suggesting best practices in an area with rainfall deficit (SDG 5, 8, 10).

In the second case, farm data is used to monitor and trace crops as they move through the supply chain, ensuring organic status (SDG 12).

The final case study describes using farm management software to screen employees, implement Good Agricultural Practices and discourage child labor (SDG 8).

MEASURING IMPACT

2.1 million acres of farmland digitized

Over 92% Client Retention Rate

Working With over 125+ clients

17 Countries

Benefiting 500,000+ Farmers across the Globe

3500+ Crop Varieties

265 Crops

92% Score On Adaptability
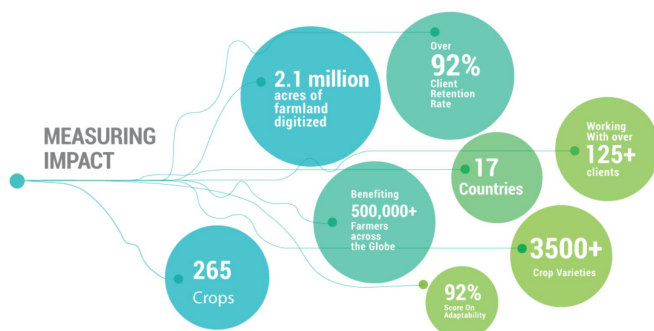
CropIn demonstrates their influence in agriculture across India and Asia through the sheer number of farmland digitized with their technologies (SDG 8). Impact measured as a product of business numbers such as number of clients and retention rate rather than a measure of sustainability factors, like a GRI report provides.

Discussion

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. This is a common strategy that speaks to a common fear of technology and change,[14] but this is perhaps becoming more prevalent with the new, more powerful than ever technologies of the fourth industrial revolution. 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 their case studies providing examples of actual people and farms who are benefitting from their technology.
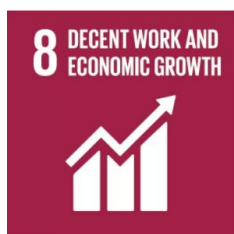
Another apparent narrative is the concept of sustainability conflated with efficiency. Both company's promise sustainability, but this is treated primarily as a promise of efficiency. This is made obvious when CropIn seems to say the same thing three ways when promising efficiency, productivity, and 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.[15]

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.

Summary of Results

	California	India
Statistical Analysis	- Companies centered around San Francisco, demonstrated shared commonalities with other tech companies - Lack of diversity - Vast majority founded in past five years - Majority of companies provide data analytics software, with the rest split between IoT and spatial imaging technologies	- Companies centered around Bengaluru, demonstrated shared commonalities with other tech companies - Lack of diversity - Nearly half of companies founded before 2011 - Majority of companies provide data analytics software, with the rest IoT technologies
Content Analysis	- Top expressed goals are: Economic Growth and Decent Work, Responsible Production and Consumption, Clean Water and Sanitation, and Industry, Innovation, and Infrastructure - Companies expressed three goals, on average - Most common words include "data", "irrigation", and "energy"	- Top expressed goals are: Economic Growth and Decent Work, Industry, Innovation, and Infrastructure, Zero Hunger, and Reduced Inequalities. - Companies expressed four goals, on average - Most common words include "farmers", "water", and "solutions"
Narrative Analysis	- Humanizes technology through anthropomorphization of fields to dispel fears - Climate Corp as a tech company applied to farming, rather than the other way around - External validation as difficult to prove, but attempted through GRI report	- Humanizes technology through case studies focused on individuals - Sustainability conflated with efficiency and all things good - External validation as difficult to prove, but attempted through demonstrating number of users and cropland

Further Discussion

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).[16, 17]

Ag Data Replacing Labor

As the case with many technologies associated with an industrial revolution, ag data has the power to replace laborers.[8] 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".[19] 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.

Equity Concerns - Access to Technology

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!".[20] Equitable access to ag data technologies will be hugely important to the successful adoption of the technology.

Equity Concerns - Data Security

Another equity-based concern raised by literature was the security of farmer data.[18] Many farmers were concerned about their data getting in the hands of agribusinesses who could take advantage of the data,[19] but with a lack of research, it is uncertain to what extent data security presents as a perceived and real risk for farmers. 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".[16] 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?".[19] 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.[3] Data security will likely become more important as big data farming becomes more widely adopted.

Application to Sustainable Development

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.[8] 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.

Recommendations

1. 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.

2. 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.

3. 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.

4. 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.

5. 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 have proved 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.

6. 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.

Appendix 1 - Actor-Network Map

The following figure is an actor-network diagram depicting key relationships for ag data development and adoption.
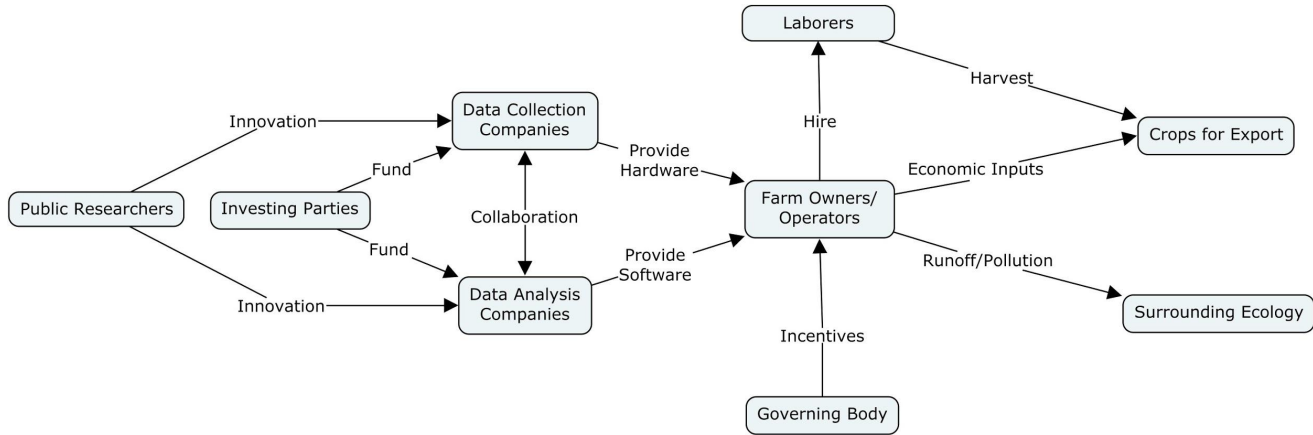
While the general relationships between actors are consistent across various contexts, the power of different actors and importance of various relationships varies greatly by specific location. For example, incentives provided by governing bodies change greatly by country and the impacts to the surrounding ecology change greatly 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).[2, 21] In India, farm owners, laborers, and crops all exhibit greater influence.[22]

Appendix 2 - Methodology

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, however, 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. An example is as follows:

I will walkthrough how I coded 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 soundbyte 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.

The companies analyzed are as follows. California-based companies analyzed: Ceres Imaging, Farmers Business Network,Mavrx, Granular, Slantrange, IntelinAir, OnFarm, Wexus Technologies, Inc., PowWow Energy, Harvesting Inc., Tule, Vinsight, Iteris, The Climate Corporation, Blue River Technology, UAV-IQ Precision Agriculture, Aerial Intelligence India-based companies analyzed: Airwood, Nebulaa, CropIn Technologies, RML Information Services Ltd., KrishiHub, Avanijal Agri Automation, Nano Ganesh Ossian Agro Automation

Finally, narrative analysis of key companies 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. Some companies also reveal certain statistics for what their technology has actually accomplished.

Bibliography

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

2. 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.

3. 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.

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

5. 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.

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

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

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

9. 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.

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

11. 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.

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

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

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

15. 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.

16. 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.

17. 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.

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

19. 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.

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

21. Mohan, Geoffrey. 2017. "As California's Labor Shortage Grows, Farmers Race to Replace Workers with Robots." *Los Angeles Times*, July 21, 2017. http://www.latimes.com/projects/la-fi-farm-mechanization/.

22. 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.