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*Partnership for* **FINANCE** *in a* **DIGITAL AFRICA**

Case study

# Launching into space: using satellite imagery in financial services

*Case Study on Apollo Agriculture and Harvesting Inc.*

Caribou Digital

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## NOTES

The views presented in this paper are those of the author and the Partnership, and do not necessarily represent the views of the Mastercard Foundation or Caribou Digital.

For questions or comments please contact us at ideas@financedigitalafrica.org.

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## ABOUT THE PARTNERSHIP

The Mastercard Foundation Partnership for Finance in a Digital Africa (the "Partnership"), an initiative of the Foundation's Financial Inclusion Program, catalyzes knowledge and insights to promote meaningful financial inclusion in an increasingly digital world. Led and hosted by Caribou Digital, the Partnership works closely with leading organizations and companies across the digital finance space. By aggregating and synthesizing knowledge, conducting research to address key gaps, and identifying implications for the diverse actors working in the space, the Partnership strives to inform decisions with facts, and to accelerate meaningful financial inclusion for people across sub-Saharan Africa.

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# Introduction

> *"[It] used to be you had to travel to a rural area to see, let alone understand, what was happening. Now, satellite data and machine learning help us see and try to understand what is going on from anywhere, and even look backward in time, which is particularly helpful since our customer base does not generally have lengthy credit histories."*
>
> **—Apollo**

Thanks to mobile technologies, Kenyans have access to an increasing array of digital financial services, including microinsurance products and pay-as-you-go solar energy solutions. Despite these advances, however, smallholder farmers in rural Kenya, who account for 70% of the country's agricultural production,[1] still lack access to affordable credit.

To help close the credit gap for farmers, innovative FinTech companies are testing whether earth observation data (i.e., imagery from earth observation satellites) can be converted into data that financial service providers can use in credit scoring models that assess a farmers' creditworthiness. Indeed, earth observation satellites, especially in rural areas, capture data that traditional means cannot—farm crop yields, mapping of crops, geotagging farmland to specific farmers, farm diversification, planting cycles, and trends in production—and that can help forecast revenues, potential repayment deficits, and timing of income.[2] While still nascent,[3] emerging evidence indicates that using satellite data can reduce the transactional costs of reaching rural farmers and, ultimately, make finance more affordable for smallholder farmers.[4]

**This case study will explore the use of satellite imagery in financial services through the work of two FinTech organizations: Apollo Agriculture and Harvesting Inc.** Specifically, this case study investigates how these organizations implemented earth observation technology and the journeys on which each organization embarked as they integrated satellite imagery into their business models and product offerings.

This study is part of FiDA's broader exploration of the promises and limitations of big data analytics in financial services, and it follows the insights presented in FiDA's Focus Note, **Can Big Data Shape Financial Services in East Africa?** A number of the financial service providers (FSPs) and FinTechs interviewed for the Focus Note identified the value of employing earth observation data to accelerate financial services, particularly given the dearth of commercially available traditional data in sub-Saharan Africa that could be used to push digital finance forward. However, because financial service providers' use of earth observation data is still nascent, the magnitude of earth observation's predictive power in credit scoring and its application in other use cases is still relatively unknown. Consequently, this case study endeavors to provide FSPs interested in leveraging non-traditional, alternative data with two relevant paths for using earth observation data. This case study explores lessons that Apollo and Harvesting learned in addressing smallholder farmer financing and provides early examples of how FSPs and FinTechs can begin working with earth observation data.

1 Okech et al., "Bridging the Gap: The Role of Data in Deepening Smallholder Farmer Financing."

2 CGAP, "CGAP and Pula Partner to Bring Satellite-Based Insurance to Farmers."

3 FiDA's Focus Note, "Can Big Data Shape Financial Services in East Africa?", highlighted a slow and steady uptake of big data and analytics in the region as well as, concurrently, a growing demand for traditional and big datasets. As discussed in the Focus Note, satellite data is proving useful for several FinTechs that are developing credit scoring models; moreover, it appears to be a relatively untapped opportunity for better reaching the unbanked.

4 Anzilott, "How Satellite Data Is Helping Drought-Stricken Indian Farmers Collect Insurance Payouts."

BOX 1

## How can earth observation data accelerate access to financial services?

Remote data captured through earth observation imagery could be a game changer for insurance and lending products by reducing operational and logistical costs. Thus far, the value proposition for FSPs is more straightforward for insurance than for credit.

High marginal variable costs employing traditional insurance methods make agricultural insurance unattractive and infeasible at scale, particularly for smallholder farmers in emerging markets.

However, organizations have been able to develop affordable and effective insurance products for farmers **using a combination of non-traditional datasets such as yield and weather data and satellite imagery** that can track weather patterns and capture changes in crops as well as the farmland itself.

Moreover, high resolution remote sensing can guide ground observations and enable organizations that process satellite imagery, like Pula, to estimate yield at the village level.

**Satellite imagery—in combination with demographics, financial, agronomic, geospatial, and psychometric data—provides sufficient detail on 'thin file clients' (i.e., clients without an established credit history) to make lending decisions.** Some providers generate credit scores using algorithms that rely on mobile phone and alternative data as well as machine learning of farmers' needs, incentives, behaviors, and agricultural activities.

The UK Space Agency International Partnerships Programme (IPP) recently highlighted the positive economic, social, and environmental impacts of space solutions in agriculture—especially in emerging markets—relative to the methods of alternative data collection (i.e., planes, UAVs, or on-the-ground teams). Their report found that, among other advantages, earth observation technology allows allows for more regularly collected data and enables the coverage of large and remote areas with a faster turnaround time.[5]



5 Caribou Digital, on behalf of UK Space Agency, "Space Solutions for Agriculture in Developing Countries."

# Liftoff

## Apollo and Harvesting in outer space

Apollo and Harvesting are driven by similar missions: to help smallholder farmers access finance and inputs that will improve their farming capabilities and potential (brief profiles can be found in **Appendix 1**). These FinTechs, however, differ in their approach to reaching this goal as will be discussed in the following section.

Apollo Agriculture was founded in 2016 by veterans of the One Acre Fund and The Climate Corporation, a digital agriculture company in the US that provides commercial farmers with customized recommendations on optimal inputs and practices through the use of earth observation data and machine learning. Because the founders came together from the two very different worlds of large-scale commercial agriculture and smallholder agriculture respectively, they realized that the machine learning tools underlying precision agriculture for US-based commercial farmers could also support smallholder farmers. Rather than focusing on providing *"the most perfect, customized recommendation,"* they needed to help smallholders access simpler tools: *"good seed, fertilizer, advice, and credit to afford those investments."* From there, **Apollo was born to use machine learning and remote sensing tools to provide smallholder farmers with a customized bundle of seed, fertilizer, agronomic advice, and insurance on credit in a more cost-effective and scalable way.** Interestingly, they have automated their supply chain so that they acquire customers, disburse products/loans, provide extension services, and collect payments without field staff. They acquire customers through highly scalable distribution channels, mainly via radio and incentivized mobile referrals (i.e., existing customers referring new customers).

The founder of Harvesting grew up in India where he witnessed the varied and immense challenges farmers face. With his background in technology, he wanted to decrease the data deficit between smallholder farmers and other stakeholders in the financial services value chain. While based in Silicon Valley, he and his network of data scientists—who were ultimately compelled by Harvesting's value proposition to join his team—came to the conclusion that remote sensing would be the most powerful and cost-effective way to fill the information gap. To this end, **Harvesting provides financial institutions with customized credit scoring models driven by artificial intelligence (AI) that employ satellite imagery and a range of complementary data sources.** By triangulating between satellite imaging data and ground-level data, Harvesting provides these institutions with details about farmers and farmland that cannot be captured cost-effectively using the collection techniques of traditional data sources. Harvesting also provides post-loan support by utilizing satellite imagery to monitor the performance of loans through the cropping cycle (using their **Farmland Monitoring Tool**, discussed in more detail below) and provides FSPs with up-to-date information on their portfolio.

Along their journey, **Apollo has also had to solve the challenge of providing services to rural customers who are difficult and costly to reach.** According to Apollo, this is a major reason that banks have been slow to reach rural customers: *"I could walk in the front door of an excellent bank and give them a perfect credit score, but it wouldn't change the fact it isn't profitable [for banks] to serve most [smallholder farmers]—their cost structure and approach means they've lost the chance at profitability long before underwriting."* Consequently, Apollo believes that, for now, they can deliver value more effectively to farmers by acquiring them directly as customers.

Conversely, **Harvesting employs a B2B model because they believe that they can reach scale by working with financial institutions** while monetizing their services as a for-profit company. Of course, it has been challenging to shift financial institutions'

perceptions of rural farmers as a core business opportunity. Nevertheless, they are seeing a slow shift and strongly believe that earth observation technology can help solve other challenges that financial institutions face, such as acquiring customers, because the data can be used to reduce the transaction costs of reaching out to rural customers. Harvesting's services can thus improve the efficiency of financial institutions' agri-lending processes, reduce the cost, increase their credit approvals, and decrease turnaround time and non-performing loans.

## Leveraging satellite imagery meaningfully requires specific tech skills and infrastructure, investment capital, and data to train machine learning models.

Government satellite missions provide systematic and accurate data free of charge. According to both Apollo and Harvesting, missions like Europe's Copernicus Sentinel and the USGS Earth Explorer deliver imagery at an appropriate resolution for them to monitor and identify farms (coupled with geotagging their farmers' locations). However, although satellite imagery may be free to download, **both FinTechs incur major costs in the process of turning the raw data into critical, analytical insights that can be used for lending purposes.**

Therefore, in order to leverage this technology, **Apollo and Harvesting had to have the right expertise on board to process and analyze satellite imagery.** For instance, both of the FinTechs' data science teams hold advanced degrees in relevant fields, including PhDs in Experimental Physics and Remote Sensing Science, and master's degrees in Engineering and Agricultural Engineering.

The required skill set is neither easily found nor inexpensive to recruit. Ideally, the data scientists working with this type of satellite imagery should have experience working with some combination of:

A software engineering,

B machine learning/data science

C remote sensing science, and

D agriculture and/or environmental science

These skill sets are key to building the infrastructure to support the processing of thousands of images and, in turn, develop the algorithms and tools necessary to transform the raw data into meaningful insights. Ideally, as with Apollo and Harvesting, these skills are built in-house. However, for organizations that cannot recruit these specialized skills in the short term, it would be prudent to contract an earth observation specialist provider to support the critical technical skills required.

> *"You need to find the people who understand what it means to take [satellite] data and interpret it; to make this concept commercially viable."*
>
> **—Harvesting**

BOX 2

## Coming into focus: providing satellite imagery for financial analysts

Numerous government actors have used satellites for various purposes, such as monitoring environmental conditions that can predict disease outbreaks and extreme weather. Missions such as Europe's Copernicus Sentinel I and II and the USGS Earth Explorer, among others, provide publicly available raw data with a spatial resolution of up to 10 meters that is updated every six to twelve days. Satellites like the Sentinel I even provide 'all weather' raw data at 10 meter resolution (i.e., they use radar satellites that can capture images through clouds).

With data at 10 meters, organizations like Apollo and Harvesting can identify and geotag farmland boundaries down to half acre farms, determine farm diversification at a gross level, and understand the environment around the farm (e.g., nearby lakes, etc.).

For example, if an organization employed 10 meter resolution imagery on a half acre farm (roughly 2000 square feet), it would be converted to 45 meters by 45 meters. With this resolution, the images obtained are about 4-bit pixels which represent multiple readings for the half acre field. Generally, for good satellite imagery one needs more than a single pixel to see what is going on, but with a handful of pixels (i.e., with 4-bit pixels), one can see what is going on clearly.

Private companies, such as **Planet**, are also contenders in the market and provide greater levels of granularity for satellite imagery with greater frequency—clients can obtain data on a daily basis. This type of data, which can be expensive to buy and has licensing limitations, is suitable for insurance companies that want to detect crop damage due to disease or weather conditions—particularly for smallholder farmers— and identify water sources (such as a wells) that data at 10 meter resolution cannot detect. Of course, because of the associated costs, such data is often unsuitable for FinTech startups, and any organization that considers buying private data should first evaluate the value of private data for their business model.

The explosion of satellite imagery and the technical skills required to turn the data into actionable information has seen a boom in the emergence of analysis companies. Organizations like **DesCartes Labs** and **Radiant** aim to serve as 'data refineries' and platforms for organizations that are not tech savvy.

A core part of Radiant's mandate is to **process** and **analyze** satellite imagery, and **offer it free** to organizations with funding from the Bill and Melinda Gates Foundation and Omidyar Network.

Although these organizations are in nascent stages, to provide meaningful analytical insights, they should first seek to  to answer this question: What type of analytical information and what layers of analysis will benefit financial services and other industries at the generic level? Every dataset will have unique qualities, and organizations may have unique needs. As the industry matures, it will be important for data platforms to answer this critical question.

Organizations that capitalize on 'science-ready', processed satellite imagery still need a certain level of technical skill to turn the data into critical insights. Nevertheless, the emergence of satellite imagery platforms can greatly improve the accessibility and understanding of satellite imagery for financial service providers.

In addition to the right people, Harvesting and Apollo needed a number of components, illustrated in Figure 1, before they could embark on their journey. For instance, **Apollo and Harvesting needed to raise the investment capital necessary to start their company operations and absorb the initial risks with equity rounds, grant resources, and/or angel investment.**

Moreover, both FinTechs needed training data—which is particularly expensive and time-consuming to collect in agriculture because it often requires an entire growing season—with which to build their models. On top of processed satellite imagery, Apollo also employed multiple sources of data in their first season to assess farmers' creditworthiness, such as psychometric, financial, and observational data. **By using multiple data sources to assess creditworthiness, Apollo was able to compare the predictive power of satellite imagery with other potential sources and use models based on the most powerful combination of this data.**

FIGURE 1

## Ingredients that allowed the FinTechs to launch satellite imagery

*Technical infrastructure to store and compute satellite data*

Harvesting has built highly scalable super computing infrastructure on cloud with 11,000 CPUs to process data continuously. This is due to the expertise their staff bring to the company.

*Training data*

Both FinTechs needed to capture data to train their machine learning models and to test and  illustrate the predictive power of satellite imagery in the model. FiDA's **Focus Note** found that FinTechs generally reported that their algorithms relied on training data, which typically either does not exist for East Africa or is low quality.

> *"...The more data that feeds through, the more accurate the models and the greater the predictive power [for customer's repayment behavior]. For a repeat borrower, it's important to know how they have performed financially, but satellite data is also useful to tell us how their fields have performed. This is useful to model for next season's crops."*
>
> **—Harvesting**

### *Proving the value of earth observation data in lending requires constantly experimenting with data-driven models—data that can only be collected infrequently and can present statistical challenges*

Testing the effectiveness of earth observation data requires long cycle times to capture data and iterate on predictive models. This can **present a challenge to organizations that may only get new data on farmers annually.** Such long cycles can constrain the pace of learning, *"which can kill you as a business"* (Apollo).

While FinTechs could potentially scale the number of customers to avoid this conundrum by loaning to potentially high-risk customers with high default rates, they would not receive valuable data for their models by doing so. Moreover, this could drain their financial and operational resources.

> *"[It will take a] long time to get the models right and to get financial institutions to believe [in it]. We are sure we will fail a few times to get it right."*
> **—Harvesting**

BOX 3

## Challenges in using satellite imagery

### *Statistical and technical challenges in training models*

A good model should use diverse data collected over a long time period and, where possible, with a large number of customers. Often good quality agricultural data is difficult to obtain. Moreover, repayment behavior is sometimes driven by factors like weather that can shift year to year, emphasizing the need for more diverse data over long periods.

### *Unrealistic expectations of clients (FSPs) of the predictive power of satellite-based credit models*

Organizations ideally partner with FinTechs because they have exhausted their in-house/traditional data sources and understand the additional value satellite imagery will provide. Harvesting, for instance, first had to streamline a microfinance institution's data systems and improve the effectiveness of their loan process with their traditional data before the organization could think about integrating satellite imagery into their credit models.

Despite the challenges, both FinTechs' initial testing with satellite imagery has been positive. Apollo's findings indicate significant predictive power from satellite imagery in terms of generating features relevant to credit models. Harvesting can use their in-house tool, **Farmland Monitoring Tool**, to understand how loaned money is being used, such as ensuring that seeds are sown and fertilizer is laid as well as by tracking the progress of crops through the cropping cycle and comparing it to historical satellite imagery. Harvesting can then alert banks about the likelihood of loan defaults or late repayments. With this information in hand, banks can protect their investment by either extending the loan period or reducing the outstanding loan amount, depending on the farmer's ability to repay the loan. Accordingly, the bank is protected against total loss and the farmer's credit is protected from the negative impact of default so that both can continue working together even in the wake of poor crop yields or unanticipated weather events.

# The FinTechs are at the beginning of their orbit, and the future is bright





Apollo and Harvesting are excited about their ambitious futures and believe that the opportunity to leverage satellite imagery (alongside other datasets) in financial services and to change FSPs' understanding of the benefits of big data is enormous and will ultimately improve farmers' incomes.

> *We believe we're going to make mistakes and the question is how quickly we can learn from them and iterate. We are proud of decisions we've made; proud of the team; proud of going out and just making loans to gather data even though it's higher risk."*
>
> **—Apollo**

## — *Scale enables profitability, but customer acquisition is still the most challenging aspect in reaching scale and profit*

Forthcoming research from the Mastercard Foundation Rural and Agricultural Finance Learning Lab (the Lab)[6] demonstrates that to date, there is not a lot of evidence for the business case of data analytics, or its impact on smallholder farmers. Nevertheless, the Lab's **forthcoming research** demonstrates that organizations are making strides in building the evidence base to support the business case for data analytics. Similarly, Apollo and Harvesting strongly believe there is a business case in leveraging satellite imagery, even more so when an organization is utilizing satellite data at scale.

> *"There are potentially half a billion farmers who are not served by financial institutions and a decent chunk of them could be if we overcame information gaps. There is a huge demand for data and increasing availability of supply. That makes sense for a business case"*
>
> **– Harvesting.**

Table 1 illustrates the various components of Apollo's and Harvesting's business models thus far.

**TABLE 1**

## Comparing components of the business model

| *Business Model Component* | *Apollo* | *Harvesting* |
|---|---|---|
| **Customer Acquisition Costs (CAC)** | It is more challenging to recover CAC for farmers with low-value loans. | Harvesting partners with FSPs that have a rural footprint and uses technology and data to reduce the marginal costs of customer acquisition. |

6 The Mastercard Foundation Rural and Agricultural Finance Learning Lab's Learning Brief, "Big data could mean big opportunity: Why we should stay excited for data analytics in smallholder finance," takes a pulse at the current state of data analytics in smallholder finance and the opportunities to build the evidence base on why and how data analytics can unlock growth in in smallholder finance. The Learning Brief will be available in late 2018.

| | | |
|---|---|---|
| **Revenue stream** | Earns input and credit margin on package of fertilizer, seed, insurance, and training. | Upfront integration costs and subscription fees (dependent on number of farmers for which Harvesting enables lending). |
| **Pricing strategy** | Shares most of the value with the customer. Price is the balance between function of value of product and cost of the product. | Revolves around type of institution, customers' financial capabilities, and social impact. For larger FSPs, Harvesting looks at on-premise solutions in order to adhere to compliance, security, and other IT policies. |
| **Key Performance Indicators** | 1 Increase in customer's income<br>2 Revenue/profitability (sample indicators):<br>a Number of customers served<br>b Repayment rates<br>c Predictability of credit model | 1 Number of financial institutions<br>2 Revenue/profitability<br>3 Number of farmers that have access to credit through Harvesting's services |

Apollo has found that with the use of satellite imagery, there is *"ample room"* for profitability at *"imminently"* achievable repayment rates, and their first season repayment rates indicate that the revenue model is sustainable. Most of the costs that Apollo faces are fixed costs (i.e., developing a credit scoring model) versus variable costs. Similarly, Harvesting notes that it is a numbers game. **Apollo argues that using satellite imagery is ultimately cost-effective because the costs are fixed and, as they scale, those costs will not increase.**

### — *To harness innovation in financial services, digital finance providers should collaborate with FinTechs*

In order to move forward, Apollo and Harvesting want to demonstrate results to help the industry mature. Moreover, Harvesting hopes that **financial institutions and other traditional digital finance providers will view FinTechs as collaborators rather than competitors.**[7] Tangible results confirming the benefits of earth observation technology in combination with a collaborative spirit among digital finance providers will unlock the potential of satellite imagery to address financial inclusion.

Moreover, like any startup in a relatively new space, both FinTechs have needs that the established industry can help them meet. While resolution in satellite imagery has drastically improved, Apollo would like to access other high quality data and meaningful information that they can use to improve their models, such as soil health, from satellite imagery. Similarly, Harvesting would appreciate more developers entering this field with an understanding of both satellite imaging and agricultural engineering. Like Apollo, they are interested in learning about new data analysis methodologies that can help them predict yield (whether through artificial intelligence or not).

## Key takeaways: FSPs must have a clear vision of why they want to leverage satellite imagery and ensure they have the in-house capacity to leverage it as well as realistic expectations of what the technology can achieve

> *"[Satellite imagery] is sexy to put on a slide deck but if it's not solving a problem, it's a hammer in search of a nail. It's hard and expensive and requires very specialized skills. Build your business without it if you can! Don't do it because you think investors want to see it or conferences want to talk about it."*
>
> **—Apollo**

The most fundamental question an organization must ask is: **what do we actually want to do with satellite imagery?** The value of earth observation data depends on the existing data an organization utilizes and the additional value satellite imagery can provide given the **high human capital cost of utilizing this technology.** It would be prudent for organizations to first be sure of the benefit of satellite imagery and reflect on **how the technology will enable them to reach their specific objective.**[8]

7 FiDA's Snapshot 10, "What makes a successful commercial partnership?," discusses the new types of partnerships that are already evolving between specialist providers, such as FinTechs, and traditional digital finance players, due to the rise of large internet players.

8 Space Solutions for Agriculture in Developing Countries," Caribou Digital on behalf of UK Space Agency, Forthcoming (2018) and the *Handbook on Remote Sensing for Agricultural Statistics* (2017) by the Global Strategy to Improve Agricultural and Rural Statistics (GSARS) elaborate on the other potential use cases of earth observation data.

Lastly, as both Apollo and Harvesting have learned, employing satellite imagery requires patience: patience to collect data, patience to receive revenue, and patience to find the funding necessary to absorb the early risks required in the liftoff stage. While the Lab's forthcoming research[9] validates that the use of data analytics in smallholder financing is still nascent, largely because it depends on a wave of digitization that is currently unfolding, the journeys presented by Apollo and Harvesting provide critical perspectives and paths forward through the challenges and promises of leveraging satellite imagery in financial services.



9 The Mastercard Foundation Rural and Agricultural Finance Learning Lab's Learning Brief, "Big data could mean big opportunity: Why we should stay excited for data analytics in smallholder finance," takes a pulse at the current state of data analytics in smallholder finance and the opportunities to build the evidence base on why and how data analytics can unlock growth in in smallholder finance. The Learning Brief will be available in late 2018.

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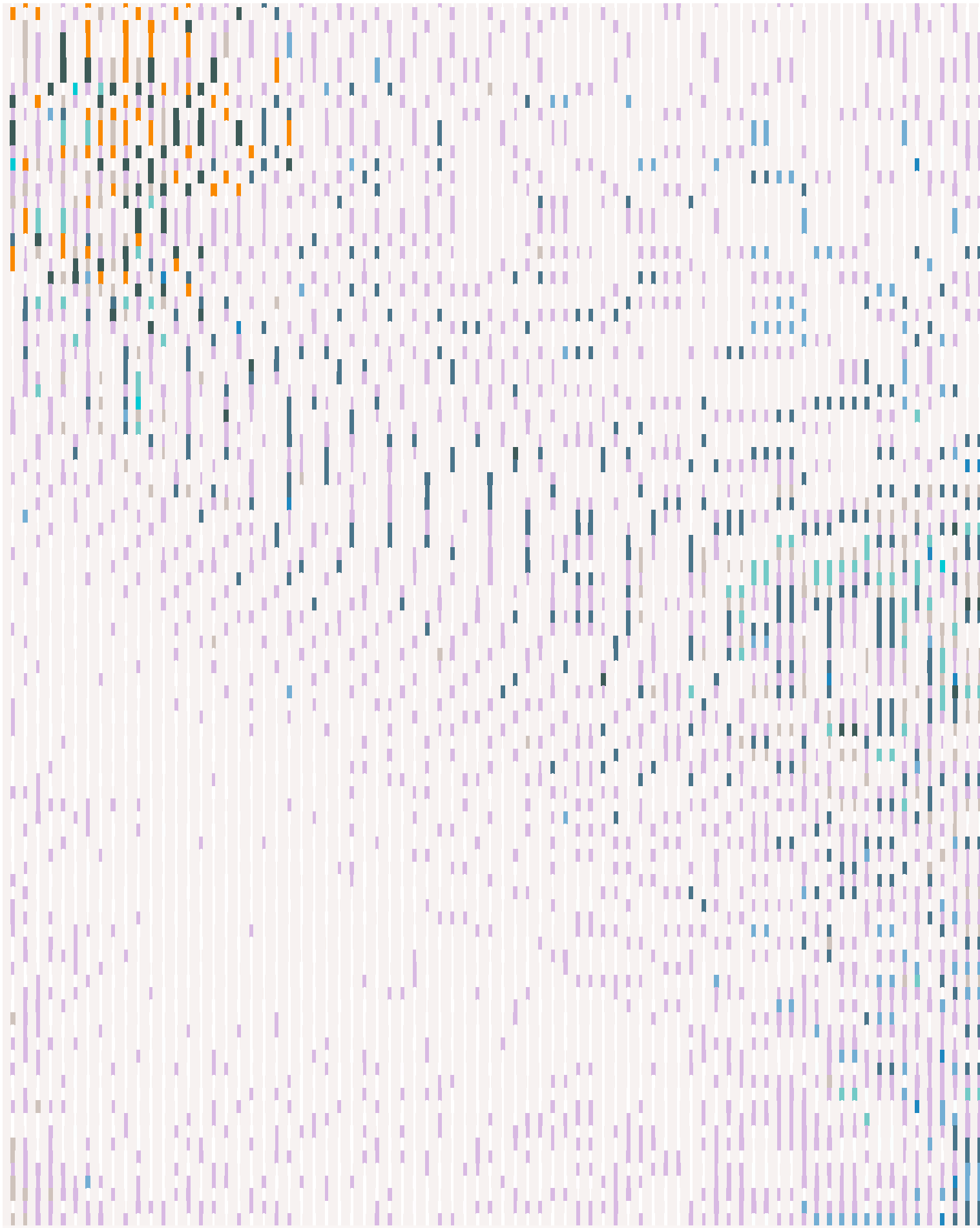
# Appendix 1
## Company Profiles

| | *Year Established* | *Offices* | *Team* | *Core Customer* | *Products and Services* |
|---|---|---|---|---|---|
| **Apollo Agriculture** | 2016 | Kenya (HQ), Amsterdam, and the US | 21 (as well as a call center and commission-based field agents) | Smallholder Farmers | Customized bundle of fertilizer and maize seed on credit, which comes bundled with insurance and advice delivered via SMS and automated voice calls to smallholder farmers. |
| **Harvesting Inc.** | 2016 | San Francisco (HQ), Bangalore | 14 | Agri-lending banks and microfinance institutions (MFIs) | Customized, artificial intelligence (AI)-driven credit scoring models, employing satellite imagery and a range of complementary data sources to financial institutions. |



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