

A Paradigm Shift in Lending to Smallholder Farmers:

The Potential of Geomapping Technology

January 2022

Acknowledgements

This research is financially supported by Small Foundation. Small Foundation is a philanthropic foundation based in Ireland that works to catalyse income generating opportunities for extremely poor people in rural, sub-Saharan Africa. Small Foundation's goal is to improve the business ecosystems that proliferate income opportunities for those in extreme poverty by expanding the access of micro, small and medium-sized enterprises to knowledge, skilled human resources, finance, technology, and markets.

This research was managed by Palladium. Palladium is a global impact firm, working at the intersection of social impact and commercial growth. For nearly 60 years, the company has been formulating strategies, building partnerships, mobilising capital, and implementing large scale programs that have a lasting social and financial impact. Palladium works with foundations, investors, governments, corporations, and communities with a global network operating in over 90 countries.

Authors

Erin Leyson, Senior Associate for Natural Resource Facilities, Palladium
Olivia Morgan, Senior Associate for Natural Resource Facilities, Palladium

Advisors

Eduardo Tugendhat, Director of Commercial Facilities for Natural Resource Systems, Palladium
Aubrey Hruby, Transaction Lead for Economic Growth, Palladium

Research Support

Jack Heringer, Analyst for Natural Resources Facilities, Palladium

Special Thanks

We are thankful to Small Foundation and the United States International Development Finance Corporation (DFC) for providing their expertise and guidance throughout the research process, in particular: Thomas Caffrey Osvold, Conor Brosnan and Sally Walkerman of Small Foundation and Bruce Cameron of DFC.

We are especially grateful to the many organizations that spoke with us to tell us about how their companies use geomapping to advance financial inclusion to SHF, including: Apollo Agriculture, Bayer FarmRise, Cropin, Koltiva, SyeComp and YAPU Solutions. We also sincerely appreciate all the other value chain actors that took the time to speak with us. This work would not have been possible without their contributions.

Table of Contents

Executive Summary	1
1. Introduction	2
2. Background & Definitions	3
3. Methodology	5
3.1. Literature Review.....	5
3.2. Ecosystem Mapping	6
3.3. Interviews	6
4. Geomapping Ecosystem	8
4.1. Types of Geomapping Providers	8
4.2. Major Trends in Geomapping Providers.....	9
4.2.1. Trends in the Geomapping Data	9
4.2.2. Trends across Providers	10
4.2.3. Trends across Intermediaries	12
4.3. Sample of Key Players.....	13
4.4. Barriers to Scale	15
5. Conclusion	16
6. References	17

Executive Summary

There are an estimated 570 million smallholder farmers (SHF) globally that produce about 35% of global food supplies, and almost 80% of food in emerging markets.¹ Despite these important contributions, SHF represent the majority of the population remaining in extreme poverty. These individuals require a 100-200% improvement in incomes to earn the equivalent of living wages.² Enabling a sustained step change in farmer incomes involves the transformation of food systems through higher on farm productivity and more efficient market linkages, all of which require access to finance and technology. However, 90% of SHF remain unable to access financing.⁴ Financial intermediaries are often reluctant to lend to SHF since they lack the tools to cost-effectively assess and quantify their risks. Together, these challenges result in a USD \$170 billion financing gap in the smallholder agricultural sector.⁵

This study explores the potential of geomapping technology to expand access to affordable financing for SHF. For the purposes of this study, geomapping is defined as the process of dropping a pin on a field and/or drawing a polygon map to identify a farm plot. The hypothesis is that geomapping can help close the SHF financing gap because it allows financial intermediaries to visualize their loans in space and monitor them more accurately. This in turn reduces the number of unknowns in a credit analysis and motivates institutions to extend more and better suited financial products to SHF.

Research identified over 160 emerging technologies grouped into three partially overlapping categories based on the primary customer focus: direct services to SHF, services for agribusiness intermediaries and services for financial intermediaries. While it is still early days for the application of geomapping, these offerings are positioned to allow intermediaries to better understand what environmental, market or even political factors may cause a set of a loans in a portfolio to underperform, based on their relative location. By collecting geomapping data, intermediaries should achieve higher rates of repayment across the SHF portfolio through an improved understanding of risks related to location and climate. Over time, intermediaries that use geomapping should move closer to achieving a financially sustainable business working with SHF.

Geomapping technology is further promising because application developers aim to deliver benefits to farmers. Some of these platforms provide locally tailored weather information, market and pricing data and crop advice that assists farmers in achieving higher yields and getting their crops to the right buyers. Taken together, geomapping can benefit both intermediaries and SHF by reducing lending risk and therefore increasing access to finance for SHF. With the right incentives, geomapping technology uptake can be increased across intermediaries—agribusinesses, cooperatives, microfinance

institutions, financial institutions, start-ups—enabling both intermediaries and SHF to thrive with increased data, transparency and understanding. The key question underlying this study is if geomapping has such potential, what keeps financial and agribusiness intermediaries from using it more broadly.

In examining how geomapping technology providers gather information, add value to it and assist intermediaries in using the data to better understand SHF risk, three key findings emerged:

1. The majority of technology providers operate in African markets, delivering mapping services and offering farmers hands-on support to overcome digital literacy challenges.
2. “SuperApps” that vertically integrate services and use Business-to-Business models are most successful. This is largely because their primary customers have existing SHF networks.
3. Intermediaries are unable to fully leverage geomapping technology because they lack either the capital to purchase technology, or the sufficient proof of added value to scale pilots.

Interviews with 28 intermediaries illustrated that barriers to scale for technology uptake centre around knowledge, capital and training. In terms of knowledge, institutions lack awareness about geomapping technology offerings as well as the value-add they can deliver to their lending activities. Technology providers need capital to grow their operations and intermediaries need capital to adopt geomapping solutions and demonstrate a proof of concept for long-term uptake. Finally, both technology providers and intermediaries require skilled professionals to implement geomapping solutions and market them to users.

Ultimately, this research informs actionable ways to scale the use of geomapping technology and reveals that the first requirement is for more evidence that demonstrates how value can be unlocked to the benefit of all actors—SHF, agribusinesses and financial institutions. One potential solution is a facility that provides both financing and technical assistance to technology providers and intermediaries. Such a facility would be uniquely positioned to address technology providers’ barriers to scale and demonstrate proofs of concept to intermediaries. By illustrating how geomapping can support the scale-up of SHF lending, this study contributes to the important efforts of countless others to promote investment in SHF with the goal of increasing their access to finance and enabling them to rise out of poverty.

¹ FAO, 2021.

² Farmer Income Lab, 2018.

⁴ Hernandez, 2020.

⁵ ISF Advisors, 2019, p. 8.



1. Introduction

Despite the growing number of innovative financial products and services available in the agricultural sector, 70% of the demand for SHF finance remains unmet.⁷ SHF often lack access to financial products because lenders and other farmer services intermediaries cannot fully understand and monitor the risks associated with this segment. This is in part because financial institutions and other intermediaries lack information about farmers as well as the capacity to properly analyse and verify information on location, yields and crops to understand SHF risk and subsequently extend a right-sized financing package to them. With limited ability to collect and analyse information, lenders remain reluctant to extend the financing needed to fill this gap.

Effecting a paradigm shift in the way the world finances SHF is important because the majority of people living in extreme poverty (under USD \$2 per day) are SHF.¹⁰ In 2013, a United Nations Environment Programme study found that a 1% increase in agricultural per capita GDP can reduce the poverty gap five times as much as a 1% increase in GDP for any other sector.¹¹ With access to the right financial products, SHF can increase yields and better meet requirements to access higher value markets, as well as adopt more climate-friendly farming practices. In this way, SHF can move out of poverty while stabilizing food supplies and helping their communities prevent and absorb the negative impacts of climate change.

This study aims to identify critical success factors required for financial and other intermediaries to integrate geomapping technology as an enabler of affordable financing to portfolios of SHF in emerging markets. The work is based on the hypothesis that geomapping technology helps to meaningfully improve the information available on SHF in the value chain as well as the capacity to gather and analyse the data to inform risk.

Increasing the availability of quality data on SHF through geomapping thereby enables better and more efficient monitoring and support of SHF, reducing the real and perceived financial risk and transaction costs associated with lending to this segment. Ultimately, increased transparency enables financial intermediaries to invest in SHF more reliably, accelerating productivity and increasing farmer incomes while also improving food security and enhancing climate resilience.

Through the literature review, ecosystem mapping and interview process, the study identified three main types of geomapping technology providers:

- Companies that sell software as a service to agribusinesses
- Companies that offer financial products or information to SHF
- Companies that sell software as a service to financial institutions

This study examines the trends across geomapping technology companies, offers relevant case studies for geomapping applications, outlines barriers to technology uptake and concludes with actionable results.

The findings suggest the need for increased early stage investment to help tech providers promote the utilization of their products and services to demonstrate how these can unlock financing and thus economic value. By establishing a facility to support geomapping uptake and train intermediaries on how to use it, this investment could help demonstrate how geomapping can meaningfully reduce risk and/or transaction cost in SHF engagements. Ultimately, an investment in the geomapping arena could support intermediaries in adopting the technology they need to increase financial access for millions of SHF around the globe.

⁷ ISF Advisors, 2019, p. 8.

¹⁰ World Bank, 2016.

¹¹ United Nations Environment Programme, 2013.

Figure 1: Geomapping Technology Can Generate Change at a Systems Level



Financing Gap

Problem

- Farmers lose up to **50%** of annual potential income due to need to access quick cash
- Globally, only **20%** of SHF are insured
- In SSA, only **10%** of land tenure is documented

Geomapping Solution

- Allow intermediaries to **monitor SHF behavior**, reducing risk and increasing lending
- Create **alternative credit profiles** that FIs can use to issue finance
- Enable agribusinesses to **trace product origins** and command a premium at the market; lifting prices for SHF

*Sources: Opportunity International; Climate Finance Lab, World Business Council for Sustainable Development



Food Supply

Problem

- SHF produce **35%** of world food supply
- SHF account for up to **80% of food supply** in emerging markets
- Climate change could force over **100 million** people into extreme poverty by 2030, due to impact on food security

Geomapping Solution

- Enhance **traceability** as a means to **higher prices**
- **Generate informed recommendations** based on local weather and land analysis to **increase yields**, i.e., crop types, fertilizers, pest/disease control, irrigation, harvest time

*Sources: World Bank, United Nations Environment Programme, Food and Agriculture Organization of the United Nations



Climate Resilience

Problem

- Agriculture emits more GHG than cars, trucks, trains and airplanes combined
- Shifting rainfall patterns pose a risk to **70%** of global agriculture
- Current food system is the main driver of **deforestation** and biodiversity loss

Geomapping Solution

- Allow lenders to understand an SHF's location-specific **climate risk** and adjust loan terms
- Enable **deforestation monitoring** and carbon credit marketing
- Recommend **adaptive and sustainable farming practices** based on changing ecological zones

*Sources: National Geographic, UNESCO



Livelihood

Problem

- Agriculture is the **main source of food and employment** for rural populations in LMICs
- **570 million** SHF worldwide live in poverty or extreme poverty
- Women comprise **43%** of agricultural labour force in LMICs

Geomapping Solution

- Accelerate lending to farmers, enabling them to grow their operations and **move out of poverty**
- **Reduce production costs** by decreasing spending on inputs and labour

*Sources: Food and Agriculture Organization of the United Nations, World Bank
*LMIC: Low and middle income countries

2. Background & Definitions

This section includes important definitions of key terms used in the study.

What is a smallholder farmer (SHF)?

There is no universal definition of 'SHF'. Generally, the size of the farming plot is used as the primary indicator, with the generally accepted measurement being plots under five hectares of land. This review adopts the respective metric used by each assessed organization.

What is geolocation technology?

There are three types of geolocation data: georeferencing, geocoding, geotagging and geomapping.¹²

- **Georeferencing** – Identifying the physical location of an object, person or field relative to a map. For example, monitoring a tractor as it plows a field via GPS-enabled asset tracker.
- **Geocoding** – Virtually searching for information related to a specific location. For example, searching for all farms growing coffee in a 100-hectare radius.
- **Geotagging** – Adding geographic location information to an object. For example, tagging a bag of produce to the location of the farm where it was grown, to track its movement through the supply chain.

What is geomapping?

Geomapping refers to the process of collecting location information and using it to assemble a map.¹³ Location data can be collected via a variety of mechanisms, most notably through the use of GPS. Specifically, for the purposes of this study, the definition of geomapping is in reference to identifying farm plots by dropping a pin on a field and/or drawing a polygon map of the plot.

What is an “intermediary”?

Any actor who directly engages with SHF and could provide or facilitate access to finance. This could be a start-up, cooperative, financial institution (FI), microfinance institution (MFI) or intermediary agribusiness involved in providing farm and post-harvest services.

Where is the SHF financing gap and why is it significant?

The global demand for SHF finance is estimated at USD 240 billion.¹⁶ Only 30% of this demand is

met, with the largest supply of finance coming from agricultural value chain actors, followed by formal and informal financial institutions.¹⁷ On one hand, large financial intermediaries have historically overlooked the SHF segment, for being too costly to reach a minimum critical mass over vast geographies. On the other hand, agricultural intermediaries tend to only offer short-term credit or inputs because doing so benefits their business.¹⁸ Therefore, a need for long-term finance, to invest in farm assets, technologies and climate change resilience remains. Currently, 98% of the long-term demand for SHF finance is unmet.¹⁹

Additionally, SHF are being left behind in climate-specific finance, despite bearing the worst of climate change's effects. Climate finance for SHF represents only 1.7% of total climate-related finance and is insufficient for them to effectively implement climate adaptation practices.²⁰

Why is the SHF financing gap significant?

From the SHF perspective, achieving a step change increase in incomes requires extracting much higher value from their relatively small plots of land. In some cases, SHF have access to more agricultural land, or are using the land for subsistence or low value crops and livestock due to their inability to secure both finance and technology. However, credit only makes sense for SHF if they feel relatively secure that they will be able to sell their product at a profit after repayment. This in turn requires reliable access to buyers and preferably the ability to meet quality standards that provide preferential prices. Thus, access to finance (as well as technology and markets) can unlock an order of magnitude increase in incomes through higher productivity, product mix, and post-harvest efficiency (e.g., reduced losses).

From the perspective of end buyers, the major challenge is ensuring that SHF can reliably achieve quality and sustainability standards on a competitive basis. This requires significant modernization both on farm and post-harvest, which in turn requires financing of new practices and technology for both the farmers and their aggregators.

For financial intermediaries and technology providers, the financing gap is significant because by failing to fully engage SHF, they miss a large customer segment made up of approximately 2.5 billion individuals and worth almost USD \$72

¹² Estes B., 2016, p.1.

¹³ Maptive, 2021.

¹⁶ ISF Advisors, 2019, p. 8.

¹⁷ Ibid.

¹⁸ Hernandez, 2020.

¹⁹ ISF Advisors, 2019, p. 8.

²⁰ Chiriack, 2020.

billion.^{21,22} The question for these intermediaries is whether the adoption of geomapping technology would cost-effectively unlock the needed financing to strengthen the SHF market, allowing them to expand and improve their businesses.

3. Methodology

The research began with a literature review of agricultural technology for SHF and geomapping technology writ large. Then, the ecosystem was narrowed down to focus on technology providers that implement geomapping in the agricultural sector within emerging markets, with over 60 providers identified. Finally, 34 interviews were conducted with top providers and intermediaries, then cross referenced with the literature review to extract insights.

3.1. Literature Review

Agricultural Technologies for SHF

The proliferation of the internet and smartphone usage across the globe has led to a growing offering of agricultural technologies. In 2020, the Global System for Mobile Communications Association (GSMA) identified over 700 agriculture-focused technology solutions offered on the market.²⁴ These agricultural technology solutions centre around five main value propositions:

- **Access to Information:** Solutions offering SHF information are the most common. The level of detailed information and advisory vary drastically – with some solutions offering generic videos of best practices and others deploying drones to offer specific crop advice at the individual farm level.
- **Access to Financial Services:** There is an increasing number of services being developed to target SHF needs, primarily focused on loans, credit scoring, input financing, savings and insurance products. These technologies help financial institutions digitize data and collect information to construct alternative credit scores.
- **Access to Markets:** Applications that create digital marketplaces enable farmers to reach buyers more easily, have greater price transparency and maintain transaction records on the cloud.
- **Traceability:** End consumers, and consequently, large agribusinesses, are increasingly demanding supply chain traceability into their products. This drive has led to solutions that use geomapping and blockchain to track products from the farm to the shelf.
- **Asset Sharing:** Because SHF lack finance to invest in large inputs, like equipment, asset sharing applications are growing. Asset sharing technologies allow SHF to essentially

²¹ Estes B., 2016, p.1.

²² ISF Advisors, 2019, p. 8.

²⁴ Phatty-Jobe A., 2020.

YAPU Solutions: Digitization, Credit Worthiness and Climate Risk Assessment for Financial Institutions



- **Summary:** YAPU Solutions facilitates access to finance for SHF. They offer flexible software solutions to support operational processes throughout the credit cycle for FIs. YAPU's main offerings centre around digital process management. They digitize and automate data gathering, credit assessment and offer data services geared toward portfolio monitoring and analysis based on traditional, geolocation and environmental indicators. YAPU provides consulting services for capacity building in green inclusive and climate finance.
- **Countries of Operation:** 10 countries in Latin America and West Africa
- **In Operation Since:** 2017
- **Number of Users:** 19 FIs
- **How They Map a Field:** At the time of farmer intake, geolocation data is collected either through smartphone GPS or selection of a location via a map. Field boundaries are not mapped.
- **Business Model: (B2B)** FIs pay for YAPU's services
 - Assessment fee for YAPU Platform (standardized software solution)
 - Periodic fee for YAPU Digital (customized software solutions) based on the number and size of the offerings used
 - Services fee for consulting products
- **Advancing Finance to SHF:** YAPU does not have any financial offerings itself, but its software solutions and consulting services help FIs to issue financing more efficiently, reducing costs and increasing access to finance.
- **Barriers to Scale:**
 - Changing legal and regulatory environments across geographies
 - MFI disinterest and resistance to engage in climate finance
 - High uptake price

share the cost of a tractor, enabling more efficient access to farming tools.^{25, 26}

Given that SHF typically have a low ability to pay for products and services that are not absolutely essential to their growing season, geomapping technology companies primarily operate under a business-to-business model (B2B). This allows technology providers to sell their services to an intermediary (often an agribusiness) and the intermediary covers the cost of platform use for all its farmers. Intermediaries, such as input suppliers and agriculture buyers and processors, are therefore the primary customers for most of the technology providers included in this study. Intermediaries are willing to pay for farmer uptake of geomapping solutions because they improve their bottom line, through higher quality products and traceability. However, in many cases, intermediaries have yet to fully leverage the data to link SHF with greater financing. Most importantly, unlike agribusinesses that value traceability, financial institutions are more hesitant to use geomapping technologies since they are price sensitive and largely unconvinced that geomapping will change the lending equation.

3.2. Ecosystem Mapping

This research identified 160 existing intermediaries and technology providers that collect geomapping data on SHF to advance financial inclusion. The process is outlined below:

1. Conducted a literature review to understand the technical aspects of geomapping, its added value to farmers and intermediaries, as well as identify key actors in the space
2. Developed a list of **160** geomapping providers and intermediaries
3. Focused on technologies where **geomapping is a core functionality**
4. Shortlisted **60** companies who focus specifically on agriculture
5. Conducted full research and analysis on these organizations, to identify:

- **Services offered** (mapping, data storage, mobile money, asset sharing)
- **Tech type** (sensors, software, drones, platform)
- **Tech features** (offline, robocalls, low data, dashboard)
- **Use case** (farmer, agricultural company, government, financial and insurance institution)
- **Business model** (target customer, revenue streams, investors)
- **Barriers to scale** (capital, infrastructure, customer acquisition)

3.3. Interviews

Researchers conducted interviews with intermediaries who finance and support SHF (those using and not using geomapping data), technology providers collecting SHF geomapping data and firms investing in agricultural technology. The interviews sought to:

- **Define and verify** geomapping data use cases for farmers, agribusinesses, governments, financial institutions, and insurance companies
- **Understand** technology providers' product offerings, engagement with SHF, and experience working with financial institutions
- **Examine** barriers to uptake (intermediaries) and scale (tech providers)
- **Identify** why intermediaries are not using geomapping data to finance SHF and understand the benefits from those that are

²⁵ Phatty-Jobe A., 2020.

²⁶ Voutier, P., 2020.

Figure 2: Interview Subjects

Company	Type of Ecosystem Actor	Current Implementation of Geomapping
Sammunati	Micro-Finance Institution	Yes
BESSFA	Financial Institution	Yes
Absa Ghana Limited	Financial Institution	In other branches of the bank*
Kshema*	Insurance Company	Yes**
Acopagro	Cooperative	Yes
Cargill	Agri-business	Yes, on numerous, separate projects. No combined effort.
Mercy Corps	Foundation / Impact Investing	Yes, through investments
Omidyar Network	Foundation / Impact Investing	Yes, through investments
Rockefeller Foundation	Foundation	Yes, through investments
Ceniarth LLC	Foundation / Impact Investing	Yes, through investments
AgDevCo	Impact Investing	No
Catholic Relief Services - Impact	Impact Investing	No
Palladium India (SHF focused programs)	Farmer Support Programs	No
Peru Catalyze (Agro Digital Platform)	Economic Development Program	Seeking platform
ChipSafer	Technology Company	Yes
Meridia	Land Mapping & Rights Organization	Yes
Hello Tractor	Technology Company	Yes
SourceTrace	Farmer Support Organization	Yes
Numer8	Technology Company	Yes
Claro Energy	Technology Company	Yes
PLACE	Data Trust	Yes
4ToldFintech	Technology Company	Yes
Bayer FarmRise	Agri-business	Yes, in India
Koltiva	Technology Company	Yes
Apollo Agriculture	Farmer Support Organization	Yes
YAPU Solutions	Technology Company	Yes
SyeComp	Farmer Support Organization	Yes
CropIn	Technology Company	Yes

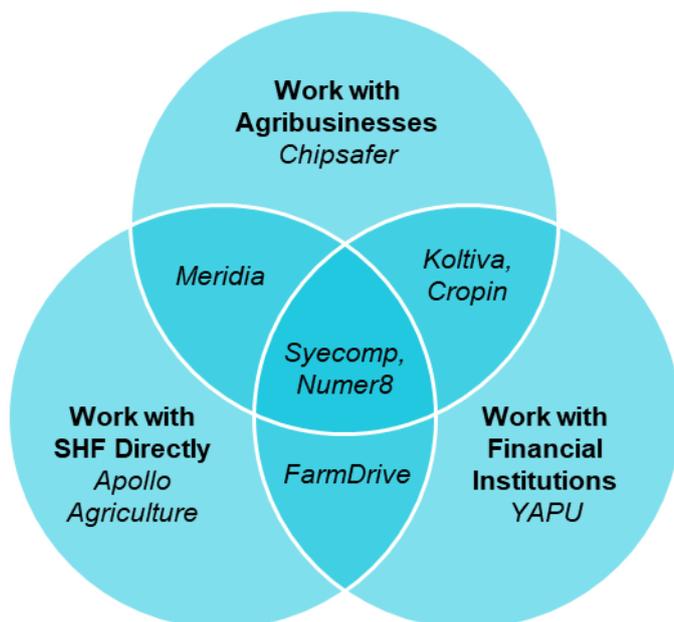
* Absa works with Avenews-GT as part of their tech incubator program, currently available in Kenya (Maeko, 2021)

** At the time of this report, Kshema is awaiting regulatory clearance from the Insurance Regulatory and Development Authority of India.

4. Geomapping Ecosystem

After laying out the geomapping ecosystem and speaking with stakeholders ranging from MFIs to technology providers to cooperatives, researchers identified key trends that impact the use of geomapping in developing markets. The study found that the most successful geomapping technology providers are those with B2B models and low-bandwidth capabilities. The interviews revealed that intermediaries' lack of awareness about geomapping's value add or lack of willingness to invest in these solutions keeps them from using geomapping services more broadly. While some intermediaries, such as large banks, have funds to adopt geomapping technology, the research found that they are currently deploying it as a pilot program in an effort to extend finance to the agricultural sector and test profitability. On the other hand, interviews revealed that smaller intermediaries with a more specific mandate of lending to SHF understand how geomapping could improve their portfolios, but lack the funds to purchase and customize the technology.

Figure 3:
Types of Geomapping Providers



4.1. Types of Geomapping Providers

Researchers identified three types of technology providers that facilitate finance to SHF, with the main distinctions being their customer type and business model.

- **Providers that Work with Agribusinesses**

Examples: Chipsafer, Cropin, Koltiva

Technology providers collect various information on SHF including geomapping (land plots and location), crop type, and soil measurements to provide useful metrics to agribusinesses, such as credit risk assessment, harvest forecasting and fertilizer and pesticide recommendations. This information is also used for traceability purposes, 'Know Your Customer' processes, and is common in highly

SyeComp: Plot Mapping, Credit Scoring and Direct Financing for SHF



- **Summary:** SyeComp offers localized digital services to farmers, agribusinesses, and financial institutions in remote sensing, plot (farm parcel) mapping, data-driven credit scoring, direct financing and access to weather and climate information and research.
- **Countries of Operation:** Ghana, Kenya*
- **In Operation Since:** 2009
- **Number of Farmer Users:**
 - Served over 1 million farmers
 - 65,000 plots mapped (including 12,500 individual cocoa farm plots mapped in Ashanti and Western Region of Ghana)
 - 120,000 farmers on the financial platform ([mFarmPay](#))
- **How They Map a Field:** SyeComp field personnel visit individual farms and map the boundaries using a rugged handheld GPS and/or tablet with a field data collector installed.
- **Business Model: (B2B and B2C)** Farmers pay USD \$13 per farm to receive SyeComp's land mapping services. Cooperatives and agribusinesses can purchase plot mapping on behalf of farmers and receive a bulk discount or pay a portion to offset the cost to farmers.
- **Advancing Finance to SHF:** SyeComp has a financial services business stream, called [mFarmPay](#). SyeComp uses SHF geolocation information, demographics and remotely sensed satellite imagery parameters in their machine learning algorithm to generate scientifically validated credit scores for farmers, which provide the basis for a loan as opposed to using land as collateral.
- **Barriers to Scale:**
 - High rural customer acquisition cost (sales, marketing, coop trainings)
 - High operating costs (Cloud computing, equipment, labor)
 - Field personnel logistics and salaries

**(new market in active feasibility and customer acquisition stage)*

scrutinized value chains such as coffee, cocoa and rubber. These providers generate direct value for SHF by providing them with tailored advice that helps them improve yields.

- **Providers That Work Directly with SHF**

Examples: Apollo Agriculture, SyeComp

This model is most prominent in entities that have a mandate to reach SHF, such as cooperatives, MFIs, and farmer support organizations. These Business-to-Customer (B2C) technology providers use geomapping data as a metric to assess risk and ultimately provide finance directly to SHF. Because SHF are the direct customers for this business type, these companies tend to have high customer acquisition costs and operate on smaller scales compared to B2B models.

- **Providers That Work with Financial Institutions**

Examples: Yapu Solutions

This provider type tends to have two lines of business. First, they help financial institutions to digitize their data, streamlining loan application processes. Second, this provider type collects farmer location and plot boundary data to help financial institutions enrich their risk assessment processes. For example, Yapu Solutions helps financial institutions understand whether or not a farmer's land is in an area at risk of increased flooding due to climate change, which allows them to build that risk into the loan terms. When intermediaries have more information about SHF risks, they can construct more accurate risk profiles and become more comfortable lending to SHF.

4.2. Major Trends in Geomapping Providers

Through the mapping exercise and a series of interviews, researchers identified key trends around geomapping technology, success factors, winning business models, data gathering, land boundary verification methods and investment challenges.

4.2.1. Trends in Geomapping Data Collection

1. Providers collect location information by cross referencing multiple methods to ensure accuracy

This study showed that most geomapping technology providers use a mix of hand-held GPS, smartphone GPS, remote sensing and proprietary algorithms crossed with legal records to collect and verify geomapping information. More specifically, most providers opt for a trained field agent that uses a hand-held GPS or smartphone GPS, because it is more cost effective than remote sensing, has a high degree of accuracy and allows contact with the local community for another layer of validation.

2. Geomapping data remains mostly siloed by value chain

There is an increased interest in the transparency of highly scrutinized value chains, such as coffee, cocoa, palm oil and rubber. Increasing consumer demand for traceability is

Bayer FarmRise: Location-based Information and Input Access to Increase Productivity



- **Summary:** Bayer operates a farm management tool and information platform for farmers across India. FarmRise provides localized information on commodity pricing for more than 300 products, agronomic advice by crop, weather forecasts, government opportunities and relevant news.
- **Countries of Operation:** India
- **In Operation Since:** 2019
- **Number of Farmer Users:** 50,000
- **How They Map a Field:** Once a farmer signs up for the FarmRise application, they will complete the “Mark My Farm” feature, which allows farmers to draw their farm on a polygon map. Extension workers are available to support farmers as needed. Bayer engages some of these farmers in their carbon offsetting program, which requires more accurate measurements. In these instances, farmers’ self-marked plots are cross-referenced with satellite imagery and audited through extension workers.
- **Business Model: (B2C)** The Bayer Corporation finances this application and generates returns by using it to market products to its farmers. FarmRise is free for farmers to use. Add-on features might be chargeable in the future.
- **Advancing Finance to SHF:** FarmRise does not currently partner with financial institutions.
- **Barriers to Scale:**
 - Low levels of digital literacy in smallholder population
 - Generational resistance to adoption of new technologies
 - Low smartphone penetration in SHF communities

driving companies to verify that their products are not made using child or coerced labour, that there was no deforestation, and that farmers are paid fair wages. For companies to do this, they need to have insights into who their farmers are and where they are farming. As a result, geomapping data providers are making products specifically tailored to these value chains. While there is not yet the same drive for transparency in staple crops, such as maize, potatoes and wheat, both the interest in regenerative agriculture and the need to identify and track products that meet higher quality standards should provide opportunities. Therefore, opportunities for these technologies emerge in tandem with the prevalence of high-value and differentiated crops and the presence of an enabling operating environment.

3. Third parties are needed to settle land boundary verification issues

Technology providers collect geomapping data in a variety of ways—drones, remote sensors, physically walking boundaries. They typically cross reference the data in a community consultation process and with local legal documentation, when possible, to achieve the highest level of accuracy. When geomapping technology providers are not able to create clear maps due to land disputes and communal land holdings, they lay out the information to their clients and allow them to make a determination based on their own criteria. SyeComp and Cropin implement this strategy. While this opens the possibility of people farming land to which they do not have a legal claim, in the case of extending financing to SHF, the interview data revealed that knowing the exact boundaries to convert a map into a land title is less important. Instead, it is more important to have a relative idea of where loans are located to reduce risks associated with external forces such as weather patterns, climate change, and pestilence.

4.2.2. Trends Across Providers

1. Most geomapping providers are “SuperApps” or “Hard-Core Mappers”

The analysis divided technology providers into four categories:

- **SuperApps:** Applications that offer farmers, agribusinesses and financial institutions a suite of services including geomapping, weather advisory, market information and access to inputs and buyers.
- **Financial Institution Service Providers:** Technologies that assist financial institutions in digitizing data, overlaying financial data with geomapping data, and providing added value through alternative credit scores and/or climate financing.
- **Hard-Core Mappers:** Technology that maps the boundary of a field or ocean area, using GPS points, satellites and/or humans walking boundaries. Added value is delivered through geolocation-related advisory and land titling services.

Apollo Agriculture: SuperApp Improving Financial Inclusion for SHF in Kenya



- **Summary:** Apollo offers farmers a bundled package that provides the core tools farmers need to succeed - financing, agricultural inputs, insurance, and digitally delivered advice - and has built the technology and operational infrastructure that makes reaching and financing farmers profitable. Apollo Agriculture uses high-resolution satellite imagery, mobile phones & payments and machine learning to assess risk and generate customer insights.
- **Countries of Operation:** Kenya
- **In Operation Since:** 2016
- **How They Map a Field:** Apollo Agriculture has a network of nearly 2,000 partner field agents who use Apollo's "Agent" app to onboard customers and gather information like field GPS boundaries. Agents are automatically tasked to visit farmers and paid commissions upon completion and quality verification of tasks. Agents use Apollo's app to walk plots and collect the GPS boundaries of each field. The location information is assessed to ensure it does not overlap with any other farmer's marked plot. The agent will also walk the farmer's home plot to have that location.
- **Business Model: (B2C)** Debt investments are refinanced into loans for farmers, which are paid back with interest at the end of the harvest. Equity investments are currently being used to cover operational expenses; expect profitability in 2022.
- **Advancing Finance to SHF:** Farmers receive “bundles” of seeds, fertilizers, location-specific advice and crop insurance with the goal of improving their yield and increasing the farmer's profitability.
- **Barriers to Scale:**
 - Access to working capital to scale services

- **Farm Management Systems:** Technology that delivers information in the form of pricing information, weather advisory, input market access, and peer advice to farmers to help them manage operations.
- **Asset Sharing and/or Tracking:** Technology that allows SHF to share the rent/purchase cost of equipment, prorating the price and increasing access to expensive inputs.

The study found that the majority of geomapping technology providers fall under the “SuperApps” and “Hard-Core Mappers” categories. This is because many technologies in this space develop along two distinct paths. First, if a technology provider has sufficient growth capital and customer base, the technology evolves to vertically integrate a range of services over time becoming a “SuperApp” through which farmers and intermediaries alike can turn for services. For instance, a technology provider might start by using geomapping data to help agribusinesses forecast supplier crop volumes and ensure no deforestation. Over time the SuperApp can evolve to partner with financial institutions, using the geomapping data to generate alternative credit scores that advance financing to SHF, similar to the Cropln case.

Second, technology providers often go down a path of specialization, becoming a “Hard-Core Mapper” wherein the company focuses solely on geomapping. An example of this is Meridia, which provides land mapping services to farmers, enabling them to access affordable land titling. In these cases, having a land map and a title transforms the land into a transferrable asset. This incentivizes farmers to make longer term investments to improve their land since they have the security that they will not be removed from it, or they can legally offer it as collateral to access finance. Just as farmers are incentivized to invest, financial institutions also see value in land titles since they provide lenders greater security that farmers own their land, can offer it as collateral and can use it to generate income.

2. Offline and low-bandwidth capabilities are key to scaling services for providers

Because SHF are often located in remote areas that are not well covered by mobile networks, offline and low-bandwidth capabilities are critical for success. Technologies that can collect data while offline and upload it when a device returns to a networked area succeed because they address the constraints of the SHF operational reality. This capability allows intermediaries to reach even the most rural SHF.

3. B2B models are most successful

Working with SHF is challenging because they are often located in rural areas, far away from each other which makes it difficult and costly to reach them and directly service them. Therefore, business models wherein technology providers sell services directly to other businesses with access to SHF networks often win out because this model allows them to reach more users faster, reducing customer acquisition costs.

Koltiva: Traceability Solutions for Highly Scrutinized Value Chains



- **Summary:** Koltiva offers an integrated suite of software platforms and applications, designed to provide value to actors across an agricultural supply chain. At the centre of Koltiva’s offerings is KoltiTrace, which allows sourcing, processing, and manufacturing clients to manage and trace their supply chain. Koltiva’s supporting applications connect supply chain actors to each other, Koltiva’s platforms, and field agents who provide a range of on the ground support services.
- **Countries of Operation:** 30
- **In Operation Since:** 2013
- **Number of Farmer Users:** 380,000 registered; 100,000 active in responsible sourcing
- **How They Map a Field:** Koltiva uses GIS land use analysis and polygon mapping for full ‘Know Your Farmer’ traceability. Field agents verify property maps with the on-the-ground-reality of SHF plots and production locations. These maps are incorporated into Koltiva’s systems, verified with land use shapefiles of protected areas and forest, and enhanced with data such as distance from mills, warehouses and banks. These maps are updated with land use change, fire hot spots, COVID-risk maps, weather, pest/disease warnings, and other data.
- **Business Model: (B2B)**
 - Large sourcing, processing, and other agribusinesses pay for software services and products along with on-the-ground support. Price depends on the combination of offerings.
 - Development organizations and governments fund projects that facilitate SHF access to on-the-ground support.
 - If KoltiPay, Koltiva’s integrated ePayment solution in Indonesia is successfully rolled out, all actors that make ePayments within Koltiva applications will pay transaction fees.
- **Advancing Finance to SHF:** Koltiva is rolling out the KoltiPay platform to deliver financing to SHF through a platform that partners with FIs to support ePayments and loan integrations. The platform is being piloted in Indonesia.
- **Barriers to Scale:**
 - Fee on loans (KoltiPay)
 - Difficulty competing with lower prices from NGO-backed products
 - Lack of smartphone coverage for SHF

Most providers offer location-based information and recommendations to farmers

4. Even technology providers that do not directly sell their services to SHF want to deliver added value to them, either because they have a social mandate to do so or because this offers additional value to their primary client. Most technology providers use geomapping data to offer farmers locally based weather advisory, crop advice and market information. This product offering adds value to the farmers and keeps them engaged, in exchange for access to their geomapping information.*
5. **Innovation is not the only success driver; capacity-building with SHF is also critical**

Although technology providers and scientists have made great strides with geomapping, the process of pinpointing, mapping and verifying an SHF's location remains labour intensive as this process requires a person to walk the boundaries of a plot with a GPS device or visit the farmer to drop a pin. Also, because digital literacy among SHF remains low, support services are needed to properly train farmers in using the geomapping information and associated services, which necessitates investment in extension workers to ensure farmers receive the added value of newly developed applications and corresponding improved agricultural practices.

6. Investment is difficult for geomapping providers to secure

Investment to scale operations and offset customer acquisition costs is difficult for technology providers to secure. However, while there are few investors specifically interested in geomapping as a stand-alone solution, there is appetite for "SuperApps" directly serving SHF because they are perceived as high impact and lower risk, especially when their customers are larger businesses.

4.2.3. Trends across Intermediaries

1. Intermediaries are either unable or hesitant to move beyond geomapping pilots

For smaller intermediaries that are convinced of the value of geomapping technology, such as cooperatives or rural MFIs, securing capital to buy a product license and adopt a solution is often a major barrier. For larger commercial banks, the price of the technology is not the principal barrier for uptake, but instead it is a current scepticism and uncertainty around serving SHF. The study found that many financial institutions serving SHF have a pilot program with geomapping providers but have not implemented it at scale due to several factors—lack of certainty around the fact that investing in SHF will improve their balance sheet, lack of understanding of the

* All technology providers we spoke with indicated they follow their local jurisdictions' data privacy requirements. This means security measures vary by country, but some of the common methods encountered were farmer consent collection, ongoing ability to opt out of information collection and anonymization.

CropIn: SuperApp for Traceability and Farmer Risk Assessment



- **Summary:** Headquartered in India, CropIn, enables various stakeholders in the ag-ecosystem, including financial services providers, to drive digital strategy and adoption across their operations. CropIn helps organizations digitize their operations from farm to fork and leverage near real-time farm data and actionable insights to make effective decisions.

CropIn's vision is to "maximize per acre value" with the mission to "make every farm traceable". CropIn intends to help agribusinesses make technology innovations accessible to growers, solve their farming challenges, and invest in their digital future. Their innovations help solve the planet's most complex problems around food security, climate change, farmer livelihood, financial inclusion, and biodiversity conservation.
- **Countries of Operation:** 56
- **In Operation Since:** 2010
- **Number of Farmers Impacted:** 7,000,000
- **How They Map a Field:** Extension workers use mobile applications to capture micro-level data including farmers in the region, land records and crop records. The data is made visible via an interactive dashboard that gives live updates on each farmer and farm.
- **Business Model: (B2B)** CropIn engages directly with agribusinesses to maximize their per acre value and make every farm traceable. In addition to its deep sense of responsibility towards the community (including farming companies, seed producers, agricultural input companies, banking institutions, insurers, government bodies, and advisories), CropIn aspires to see millions of farmers sustainably benefit from their technology. CropIn's solutions can be customized to meet specific client needs.
- **Advancing Finance to SHF:** CropIn's SmartRisk solution, a machine learning-enabled platform, helps lending institutions validate farm information furnished by farmers by comparing it with historical and predictive insights. It allows banks and insurance companies to underwrite loans and process credit to farmers. The statistical models are built using satellite image processing and machine learning, to enable lenders to forecast farmer's yield and potential risk.
- **Barriers to Scale:**
 - Slow adoption rate due to lack of intermediary awareness and ability to invest in technology
 - Limited access to high-speed internet

technology, varying regulatory compliance across countries, and resistance to change.

2. COVID-19 has significantly decreased FIs' and agribusinesses' willingness to pay for information on SHF

COVID-19 has diminished economic activity and hurt business for countless financial institutions, agribusinesses, and other intermediaries. As a result, intermediaries are now less willing to pay for geomapping data on SHF, a group currently perceived as high risk and low return. One provider interviewed reported a 50% decrease in revenue from intermediaries in 2020. As of late 2021, providers were starting to see an increase in intermediaries' willingness to pay for geomapping data, specifically to help address some of the worst ramifications of the pandemic on SHF. These providers are projecting a return to pre-pandemic revenue levels for 2022.

4.3. Sample of Key Players

* This sample was selected to illustrate diversity in services and business models across geomapping technology providers.

Figure 4: Sample of Geomapping Technology Providers

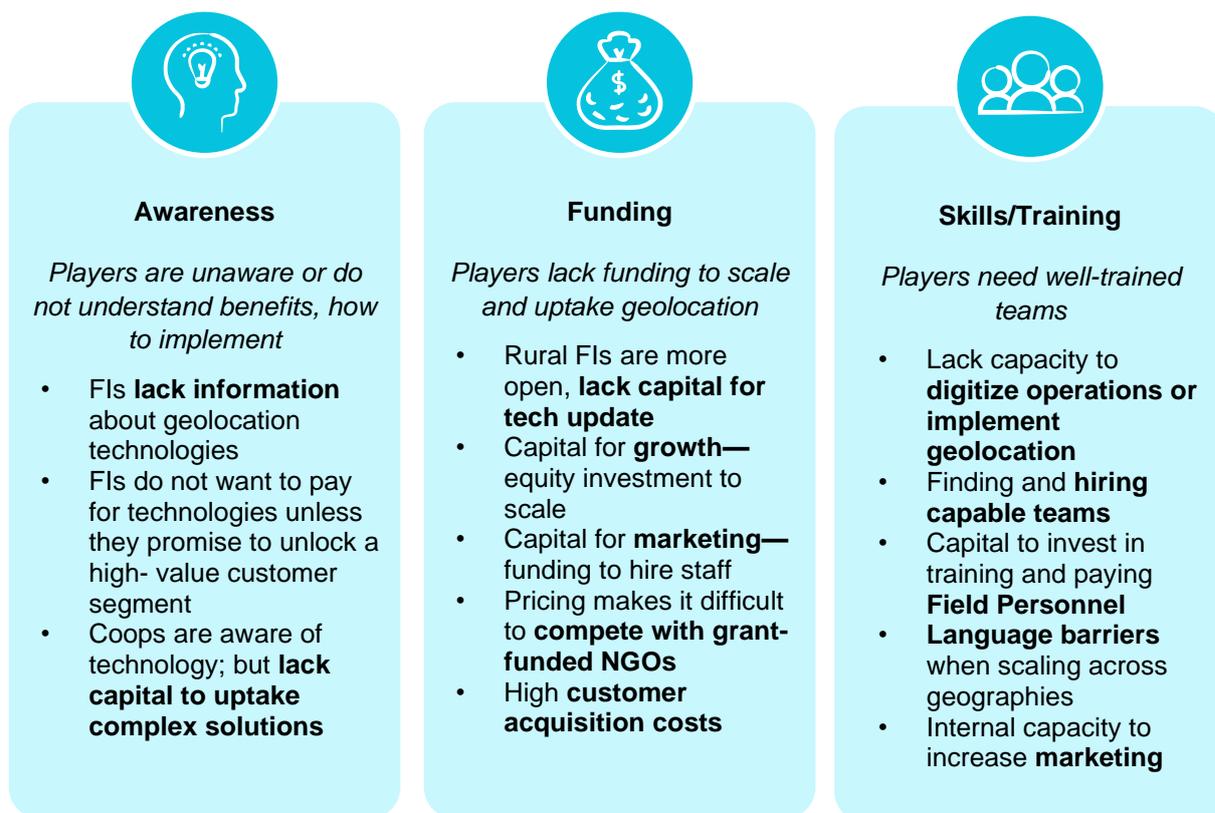
Name	Services	Business Model	Type	Implementation of Geomapping Data
Koltiva	<ul style="list-style-type: none"> • End-to-end software solutions for traceability, Know Your Customer and Know Your Farmer • Provides Koltipay and Koltimart mobile money services 	<ul style="list-style-type: none"> • Agribusinesses pay for software services • Development organizations and impact investors provide capital for scaling 	SuperApp	<ul style="list-style-type: none"> • Polygon mapping for farm size, yield, age • Mapping of approved agricultural use areas, restricted animal conservation areas • Distance maps to show farm plot in relation to mills and agents, warehouse locations and banks
Cropln	<ul style="list-style-type: none"> • SaaS solutions to max per acre value • Aim to make every farm traceable • Digitize farms with data storage, machine learning, satellite monitoring 	<ul style="list-style-type: none"> • Agribusinesses, cooperatives, governments and FIs pay for software packages 	SuperApp	<ul style="list-style-type: none"> • Using satellite imagery and historical yield and cultivation data to advise FIs on farmer credit risk and allow for real time monitoring • Extension workers geotag plots
Apollo Agriculture	<ul style="list-style-type: none"> • SuperApp that bundles farmer services i.e. financing, inputs on credit, information, insurance, and market access 	<ul style="list-style-type: none"> • Farmers pay for services • Funding from Impact Investors 	SuperApp	<ul style="list-style-type: none"> • Use satellite imaging of fields to build credit profiles for customers
SyeComp	<ul style="list-style-type: none"> • Optical and Radar Satellite monitoring and mapping • GPS data to provide location-specific weather information • Credit scoring and financing (Mfarmpay) 	<ul style="list-style-type: none"> • Farmers pay for mapping and FIs pay for farm mapping and monitoring through Mfarmpay 	Hard-Core Mapper	<ul style="list-style-type: none"> • Remote sensing, farm mapping and GPS data crossed with data from D.O.T. and Dept. of Ag. to facilitate access to markets and credit • Credit scoring mechanism used for lending

Figure 4: Sample of Geomapping Technology Providers

Name	Services	Business Model	Type	Implementation of Geomapping Data
Numer8	<ul style="list-style-type: none"> • SaaS company providing location data, land assessment and weather information to fisherfolk • Ofish- provides fishing zone advisories, weather data, traceability • QresQ- infrastructural monitoring, soil monitoring and land assessment with aerial land survey 	<ul style="list-style-type: none"> • Fisherfolk paying subscription fees • Collect fee for fish sold on platform 	Hard-Core Mapper	<ul style="list-style-type: none"> • Provide information on expected catches and weather forecasts with FIs to de-risk lending to groups of fisherfolk
Meridia	<ul style="list-style-type: none"> • SaaS company using GIS technology and field worker mapping to reduce land formalization costs 	<ul style="list-style-type: none"> • Agribusinesses pay to get their suppliers land titles • Financing from Development Institutions subsidizes costs • Farmers pay a portion 	Hard-core Mapper	<ul style="list-style-type: none"> • Use land titling to incentivize farmers to make larger, longer-term investments in their fields to increase production • Farmers use title documents to secure credit
YAPU Solutions	<ul style="list-style-type: none"> • FinTech company that combines self-reported farmer data – crops grown, farm size, input use – with public data to generate credit analysis & assessment, productivity, climate, environmental, and adaptive capacity scores 	<ul style="list-style-type: none"> • FIs purchase software and consulting services • Development Organizations and Impact Investors fund projects through grants, debt, and equity 	FI Software Provider	<ul style="list-style-type: none"> • Using geomapping and localized weather and climate risk information to reduce loan origination and portfolio monitoring costs • Data enables FIs to support SHF with climate change mitigation through locally tailored loan products
FarmRise	<ul style="list-style-type: none"> • Application that allows farmers to plot their farm boundaries and track input/outputs to calculate P&L 	<ul style="list-style-type: none"> • Bayer finances the app • Farmer-suppliers use app for free to get information and inputs 	Farm Management System Agribusiness-owned	<ul style="list-style-type: none"> • “Mark My Farm” feature allows farmers to drop pins and draw location
Hello Tractor	<ul style="list-style-type: none"> • Platform that allows farmers to access tractors at an affordable rate through equipment sharing • Remote sensors on tractors collect data on hectares ploughed 	<ul style="list-style-type: none"> • Tractor owners, dealers, and users pay to book tractors and use the app 	Asset Sharing and/or Tracking	<ul style="list-style-type: none"> • Making tractor usage data (frequency of renting and hectares ploughed) available to farmers and FIs who can use it to measure level of effort and farm size
ChipSafer	<ul style="list-style-type: none"> • Platform that uses GPS-enabled collars to track cattle and detect health or spatial anomalies 	<ul style="list-style-type: none"> • Agribusinesses and/or ranchers pay for hardware and platform access 	Asset Sharing and/or Tracking	<ul style="list-style-type: none"> • GPS-enabled asset tracking to reduce theft, increase efficiency, and ensure cattle health • Using collars to track tractor and worker effort

4.4. Barriers to Scale

Figure 5: Summary of Barriers to Scale



The study surfaced a variety of barriers to scale and uptake across the SHF farmer financing ecosystem that were common to technology providers, financial institutions, agribusinesses, and cooperatives. These barriers signal the need to invest in knowledge building activities, unlock capital to help technology providers grow and cultivate a talent pipeline to develop new services and implement them within intermediaries.

1. Awareness and Knowledge Gaps:

Players are unaware or do not understand the benefits of geomapping technology nor how to effectively implement it

The study revealed that across intermediaries, a major barrier to uptake was a lack of information around what geomapping technologies currently exist on the market, the value they deliver and how they can enhance work with SHF. Specifically, financial institutions lack information about geomapping technologies as well as knowledge of how this information can help them better understand SHF credit risk. Furthermore, intermediaries are not inclined to pay for geomapping technologies because they remain unconvinced that these tools will help them unlock a valuable customer segment—SHF—despite the demonstrated financing gap.

2. Funding Gaps: *Players across the ecosystem lack funding to scale and uptake geomapping services*

All players from MFIs to agribusinesses to technology providers require funding to enhance their use of geomapping technology. Wherein technology providers seek capital to grow their operations by developing new services and moving into new markets, intermediaries seek capital to pilot the technology so that they can learn about their value before fully investing.

3. Skills/Training Gaps: *Players need well-trained teams to operate and scale technology offerings*

Technology providers and their clients lack the skills necessary to efficiently scale and deploy geomapping technologies. Intermediaries express the need for trained professionals to implement geomapping applications and software, as well as find ways to properly integrate it with current service offerings. Technology providers express the need for trained teams to work on SHF capacity building in the field. Finally, technology providers signalled the need for marketing personnel to sell their products. Interventions demand investment in talent pipelines for software developers, field personnel and marketing professionals.

5. Conclusion

Although geomapping remains underutilized, the technology has the potential to help close the SHF financing gap and catalyse systemic change for millions. Where SHF face barriers to access finance due to a lack of land title and credit history, geomapping can help close the gap by creating alternative credit scores that help reduce perceived lending risk. In doing so, geomapping technology assists intermediaries in supplying SHF with the funds needed to make long term investments in their operations, resulting in increased yields and profitability. Further, as the global community works to combat climate change, geomapping is a key tool that is helping intermediaries to unlock climate finance opportunities. By mapping SHF plots and relative locations, intermediaries can increase their understanding of SHF climate risks allowing them to adjust lending terms and extend climate financing to SHF who shoulder the brunt of climate change's negative effects. Despite the promise of geomapping technology, the research illustrates that geomapping remains untested at scale because intermediaries lack funding, technical support, skilled professionals, and incentives to drive behavior change. With that in mind, this research highlights the need for strategic investment to increase intermediaries' uptake of geomapping technology. One such strategy is to develop a financing facility that provides focused funding and technical assistance to technology providers and intermediaries.

The potential facility could motivate the paradigm shift that SHF need to achieve living wages and eventually rise out of poverty. By providing capital for intermediaries to embed geomapping technologies in their operations, a facility could encourage wider geomapping uptake and increase SHF data availability to reduce lending risk. Through technical support in the form of technology implementation assistance for intermediaries and marketing services for technology providers, such a facility could further promote the adoption of geomapping technologies by making the expertise needed to sell and operate it more available. Finally, by connecting key players across the agriculture, technology and finance spaces, a facility could lay the foundation for a transformative dialogue that connects financial institutions to the technology providers they need to better understand SHF dynamics. By working with private investors, donors, aid agencies and development finance institutions to empower ecosystem players to fully leverage geomapping technology, a facility could help fill the SHF financing gap, while also driving wider economic and environmental improvements that benefit society at large.



6. References

- Chiriac, D., Naran, B. (2020). *Examining the Climate Finance Gap for Small-Scale Agriculture*. Climate Policy Initiative and IFAD. https://www.ifad.org/documents/38714170/42157470/climate-finance-gap_smallscale_agr.pdf/34b2e25b-7572-b31d-6d0c-d5ea5ea8f96f
- Christen, R., Anderson, J. (2013). *Segmentation of Smallholder Households: Meeting the Range of Financial Needs in Agricultural Families*. CGAP. https://www.cgap.org/sites/default/files/researches/documents/Focus-Note-Segmentation-of-Smallholder-Households-April-2013_0.pdf
- Christiaensen, L., Demery, L., and Khul, J. (2011). *The (evolving) role of agriculture in poverty reduction: An empirical perspective*. *Journal of Development Economics* 96(2): 239–54.
- Esties, B. (2016). *Geolocation – The Risk and Benefits of a Trending Technology*. ISACA Journal. <https://www.isaca.org/resources/isaca-journal/issues/2016/volume-5/geolocation-the-risk-and-benefits-of-a-trending-technology>
- Farmer Income Lab (2018). *What Works to Increase Smallholder Farmers' Income?—A Landscape Review, Working Draft for Discussion*. https://www.farmerincomelab.com/sites/g/files/jydpvr621/files/2019-09/What%20Works_FINAL_9.19.pdf
- Foley, J. (2015). *A Five Step Plan to Feed the World*. National Geographic Magazine. <https://www.nationalgeographic.com/foodfeatures/feeding-9-billion/>
- Food and Agriculture Organization of the United Nations. (2021). *Small Family Farmers Produce A Third Of The World's Food*. <https://www.fao.org/news/story/en/item/1395127/icode/>
- Food and Agriculture Organization of the United Nations. (2021). *What is Soil Carbon Sequestration?* FAO Soils Portal. <https://www.fao.org/soils-portal/soil-management/soil-carbon-sequestration/en/>
- Hallegatte, S. & Walsh, B. (2020). *COVID, Climate Change and Poverty: Avoiding The Worst Impacts*. World Bank Blogs. <https://blogs.worldbank.org/climatechange/covid-climate-change-and-poverty-avoiding-worst-impacts>
- Hernandez, E., Akkireddy, J., van der Velden, I. (2020). *Sowing the Seeds of Innovation for Smallholder Finance*. CGAP and IDH, The Sustainable Trade Initiative. <https://www.idhsustainabletrade.com/uploaded/2020/06/Action-Paper-Sowing-the-seeds-of-innovation-for-smallholder-finance.pdf>
- ISF Advisors. (2019). *Pathways to Prosperity, Rural and Agricultural Finance State of the Sector Report*. https://isfadvisors.org/wp-content/uploads/2019/11/2019_RAF-State-of-the-Sector-10.pdf
- Jeff Schahczenski, J., Hill, H., (2009). *Agriculture, Climate Change and Carbon Sequestration*. National Sustainable Agriculture Information Service. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs141p2_002437.pdf
- Maeko, Tshepo. (2021). *Absa using Tech to Drive Growth in Africa's Agriculture Marketplace*. Absa. <https://www.absa.africa/absaafrica/our-stories/our-voices/2020/absa-using-tech-to-drive-agriculture-growth-in-africa/>
- Maptive. (2021). *Make Sense of Your Location Data with Geo Maps*. Maptive. <https://www.maptive.com/what-are-geo-maps/>
- Mundy, O. (2021). *Catalogue of Geospatial Tools and Applications for Climate Investments*. IFAD. https://www.ifad.org/documents/38714170/44188440/IFAD_Innovation_COP26_Catalogue-FIN2-GeoData.pdf/2883d14e-84ce-76e2-1f25-9d7252b5c9cc?t=1636469089952
- Opportunity International. *Financing Smallholder Farmers to Increase Incomes and Transform Lives in Rural Communities*. <https://opportunity.org/content/News/Publications/Knowledge%20Exchange/Financing-Smallholder-Farmers-Opportunity-International.pdf>

- Phatty-Jobe, A. (2020). *Digital Agriculture Maps 2020 State of the Sector in Low and Middle-Income Countries*. GSMA. <https://www.gsma.com/r/wp-content/uploads/2020/09/GSMA-Agritech-Digital-Agriculture-Maps.pdf>
- Rapsomanikis, G. (2015). *The Economic Lives of Smallholder Farmers: An Analysis Based on Household Data from Nine Countries*. Food and Agriculture Organization of the United Nations. <https://www.fao.org/3/i5251e/i5251e.pdf>
- Sommerville, M. (2020). *Using GPS Technology to Secure Land Rights for Farmers In Africa*. World Business Council for Sustainable Development. <https://www.wbcsd.org/Overview/Panorama/Articles/Using-GPS-technology-to-secure-land-rights-for-farmers-in-Africa>
- The Climate Finance Lab. (2019). *Blockchain Climate Risk Crop Insurance*. <https://www.climatefinancelab.org/project/climate-risk-crop-insurance/#:~:text=In%20developing%20countries%2C%20only%20,falls%20further%20to%20just%2003%25.&text=Insurance%20can%20be%20expensive%2C%20and,of%20delayed%20or%20absent%20payouts>
- United Nations Educational, Scientific and Cultural Organization (UNESCO) and World Water Assessment Programme (WWAP). (2018). *Nature-Based Solutions for Water: The United Nations World Water Development Report*. <https://www.unwater.org/publications/world-water-development-report-2018/>
- United Nations Environment Programme. (2013). *SHF Farmers Key to Lifting over One Billion people Out of Poverty*. <https://www.unep.org/news-and-stories/press-release/SHF-farmers-key-lifting-over-one-billion-people-out-poverty>
- Voutier, P. (2020). *SHF AgriTech Business Models: High-Potential Models Emerging in Southeast Asia*. Grow Asia. http://exchange.growasia.org/system/files/SHF%20AgriTech%20Business%20Models_FINAL_0.pdf
- World Bank. (2016) *A Year in the Lives of SHF Farmers*. <https://www.worldbank.org/en/news/feature/2016/02/25/a-year-in-the-lives-of-SHF-farming-families>



FOUNSMALLDATION