CGAP

BRIEF

Using Satellite Data to Scale Smallholder Agricultural Insurance

Research shows that agriculture insurance can help smallholder families become more resilient. It allows families to better manage risks, invest more confidently in their diverse livelihoods, and increase productivity. However, despite significant progress in offering smallholder agricultural insurance, scale remains difficult in many parts of the world, especially in Africa. Increasingly, satellite data are being explored to drive further innovation in smallholder agricultural insurance, as illustrated by a CGAP and Pula collaboration in Nigeria and Kenya. This Brief shares lessons from this collaboration and suggests a practical way that satellite data can be used to significantly reduce delivery costs of area-yield index insurance offered to smallholder families in Africa.

Of the 2 billion people living in smallholder households worldwide, an estimated 198 million have some form of agricultural insurance coverage (Hess and Hazel 2016). The geographic distribution of those insured individual smallholders is highly uneven. Most of them are concentrated in China (160 million) and India (33 million), thanks to the sheer size of their smallholder populations and large-scale government programs that subsidize premiums. There are only about 1 million insured smallholders in the rest of Asia, 3.3 million in Latin America, and fewer than 1 million in Africa. In Africa, that's less than 1 percent of smallholders.

Growing efforts to promote scale in smallholder agricultural insurance are motivated by the mounting evidence that it helps smallholders increase investments in more productive farming and nonfarming ventures while they manage several risks (Liu et al. 2013; Karlan et al. 2014; Cai et al. 2015). However, public and private actors that offer smallholder agricultural insurance face persistent challenges that have limited the uptake of agricultural insurance among smallholders. These challenges relate to the relatively high costs of determining product features that meet smallholder insurance needs, defining an adequate actuarial design for such products, and delivering these to customers who live in sparsely populated rural areas.

Today, many smallholders are covered by index-based insurance. Unlike traditional agricultural insurance, which requires insurers to visit clients' farms to assess loss claims, index insurance allows providers to determine whether a payout is warranted based on an index that can be observed remotely (e.g., rainfall levels, temperature, or regional yield averages). This type of insurance has the potential to reduce delivery costs, but it is not easy to implement because it relies on the quality and quantity of data. It requires providers to identify a strong historical correlation between a particular index figure and insured losses suffered by individual clients in a geographic area. This correlation allows providers to use the index to predict clients' losses. The risk that loss predictions made by the index are not accurate is known as basis risk.

Satellites increasingly collect valuable data that could be used to develop more accurate index-based insurance. As one of the pioneers, the Indian Government explored satellite data applications to reduce basis risk as part of its National Agricultural Insurance and Weather-Based Insurance Schemes, which reach over 30 million smallholders (Clarke et al. 2012).

While satellites can provide data on rainfall, temperature, and other potential indices, they cannot measure the farm yields that must be correlated to the index. This means that even insurers with access to satellite data still need access to accurate farm yield data in the regions covered. Collecting farm yield data can be difficult and expensive—the lack of reliable yield data is one of the main barriers to index insurance in Africa. To overcome these challenges, practitioners in the region are exploring innovative satellite data applications on index-based insurance.[1]

As part of these innovation efforts, CGAP partnered with Pula, an insurance and technology company that targets smallholders in Africa and Asia. Our work focused on Nigeria and Kenya—where Pula sought to test how satellite data could be used to increase smallholder outreach by significantly reducing the cost of area-yield index insurance products. Pula's work with local agribusiness partners has enabled it to compile significant amounts of audited yield and other smallholder data—like fertilizer and seed use—as part of an already established commercial market for agriculture insurance products in both countries. Box 1 presents a description of the main types of index-based insurance products available in these markets.

Results from the collaboration offer a practical application for satellite data to help scale smallholder area-yield insurance, which may be useful for practitioners and development actors to build on and adapt to their different contexts. The proposed application departs from the prevailing approach of trying to correlate individual farm yields with satellite data and instead uses satellite data to define a new yield sampling method within those communities insured. This approach significantly reduces the costs of rolling out large-scale area-yield index insurance for smallholders.

From the client's perspective: The quest for insurance at scale

Our work focused on area-yield index insurance because its product features matched risk management needs

1 E.g., see Flatnes and Carter (2017) and IFAD (2017) on how satellite data can help reduce basis risk in index-based insurance.

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Box 1. Main types of index-based agricultural insurance

Area-yield index insurance is one type of index-based insurance. As an index, it uses a specific percentage of the historical average yield in the insured area (e.g., 50 percent of the average historic yield for a given municipality insured). After each agricultural season, the insurer samples yields in the municipality or unit of area insured and determines if payout is warranted should current average yields fall below the index established in the policy. This means that the insurer needs to collect only a sample of farm yields within the municipality, rather than measure yields for every individual client in the area, to determine payout. Insurers then need to undertake yield sampling campaigns during every harvest period for each crop insured.

Another type of index-based insurance is weather-index insurance. It uses an index that is related to weather variables (e.g., rainfall, temperatures, wind speeds). Weather-index products tend to cover weather-related shocks only, potentially excluding other natural shocks, like pests and diseases, that could lower collective yields. They do not require any yield sampling within the unit of area insured, unlike area-yield index insurance, therefore, the logistics involved in their implementation tend to be simpler.

identified by Nigerian smallholders. CGAP's nationally representative survey of smallholder households in Nigeria finds smallholders' greatest interest is in agricultural insurance (34 percent), followed by life (16 percent), and medical (15 percent) insurance.[2] The most common shocks affecting the agricultural activities of smallholders in Nigeria are pests and diseases (64 percent) followed by weather-related events (40 percent). However, less than 1 percent of smallholders in Nigeria reported having any form of formal insurance. And over half of smallholders report low levels of trust in formal financial institutions.

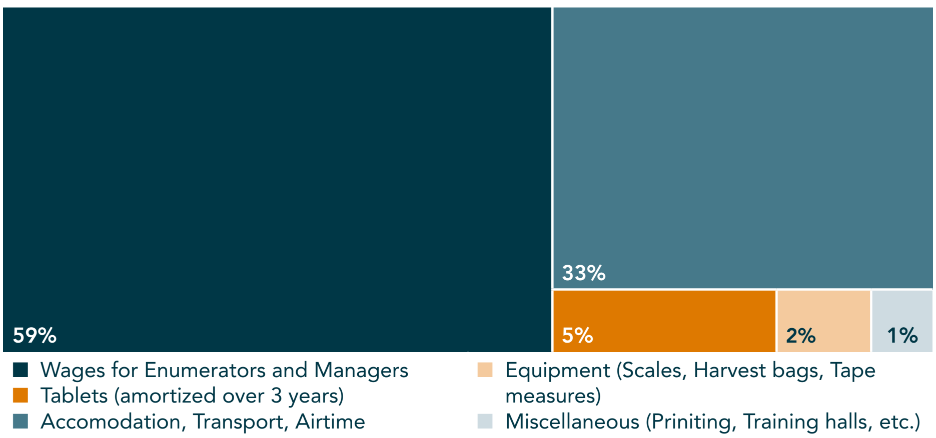
These insights are consistent with Pula's experience in the region. Pula has seen a rapid expansion of its area-yield index product, which constitutes 80 percent of its regional portfolio in Africa and Asia. Pula's experience suggests this is because the product features appeal to smallholders. Area-yield index insurance offers coverage against any shock affecting collective yields, including those related to pests, diseases, and weather events.

This is something smallholders in Nigeria value, especially when the insurance product offered by Pula protects things they need, like agricultural inputs (e.g., fertilizers and seeds) and agricultural credit contracts with lenders. Further, smallholders tend to trust and understand area-yield products because these products require insurance representatives to occasionally visit the community, monitor yields, and interact with local leaders. This responds to the low levels of trust smallholders have in the overall financial sector. And the large smallholder population in Nigeria, estimated at about 19 million, is highly underserved when it comes to insurance, which represents a significant growth opportunity for Pula.

Despite the advantages of area-yield index products from the customers' perspective, insurers face a significant disadvantage. As described in Box 1, the field sampling required by insurers to determine average yields in each community or unit of area insured is costly and imposes a heavy logistical burden—it entails sampling campaigns at different times in different regions for different crops—to scale coverage nationwide. In the Pula context, farm yield measurements (also known as crop cuts experiments) are notoriously expensive—each costing US$25–50. See Figure 1.

Pula's other weather-index products (see Box 1)—which represent the remaining 20 percent of its portfolio—are considered better suited for smallholders for whom weather shocks are a primary concern. In such cases, Pula invests in onsite marketing campaigns

Figure 1. Cost breakdown of a yield measurement or crop cut experiment



Source: Pula

2 For more information about the survey methodology and results see Anderson et al. (2017). Note that, in other countries surveyed, smallholders seem to prioritize life and medical insurance over agricultural insurance. Therefore, this preference is highly contextual.

to explain its weather-index product to farmers. Although weather-index insurance does not require visits to the community, Pula considers it necessary to visit communities to monitor yields and to effectively manage basis risk. The related costs incurred by Pula may not make weather-index insurance cheaper than area-yield index products. However, the logistics of rolling out weather index products are simpler.

Toward an applied satellite and yield data correlation model

From July to November 2017, Pula collected over 1,000 direct yield measurements across several north-central Nigerian states and compiled about 15,000 yield measurements from the past seven years from local agribusiness partners who work with smallholders. These local partners invest in collecting accurate yields because this helps them achieve some of their goals, such as verifying whether inputs or technical assistance offered are effective, monitoring counterfeit inputs, and reducing agricultural credit default. These yield measurements are for rice and maize produced by farmers who generally owned 1–5 acres of land. The data include GPS coordinates and variables related to seed and fertilizer use. CGAP and Pula engaged several analytical firms to evaluate how strong a correlation could be achieved between the yields observed and the satellite data and to assess whether this correlation model could be used to predict yields by looking at certain variables coming from satellite data.[3]

Initial results showed that statistical models based on satellite data did not explain individual farm-level yield observations well (only 10–20 percent of farm yield variations were explained). However, the models did provide a better prediction of the average yields in Local Government Areas (LGAs).[4] In this case, 60 to 80 percent of the variation of average yields was explained. These results were not deemed good enough to be applied by partner insurers and reinsurers given that the predictive power is considered low, even at the LGA level.

The challenge to define an implementable satellite and yield data correlation model that would reduce smallholder insurance costs led to innovating in unexpected ways. The initial results forced us to rethink our analytical approach. Noting that aggregating analysis at the LGA level improved the prediction, we reformulated the initial question. Instead of using satellite data to predict individual farm yields, we focused on using these data to define the boundaries of units of area insured that are much larger than the LGA and that have a common yield distribution.

By aggregating the area units further, we sought to improve the ability to predict average yields in these areas while reducing the total number of crop cuts or yield measurements required. Common yield distributions within these insured units could help maintain the basis risk levels already achieved in the current market. Over time, as more yield samples are gathered, basis risk could be further reduced.

We also realized that, despite having yield data from local agribusiness actors who had strong incentives and expertise to ensure accuracy, yield observations were highly concentrated in the range of 2–5 metric tons per hectare. This means there was little variation in yields observed, which makes it difficult for statistical models to find a correlation with satellite data. Because lower yields by the more vulnerable households were not observed much, the model could not determine a stronger yield and satellite data correlation.

To get more variation in yields observed, Pula collected over 2,500 additional yield measurements in north-central Nigeria between January and May 2018. This time, efforts were made to sample areas where poor yields were expected. In addition, a large dataset from western Kenya with over 6,300 observations was added to test the model, given that the area seemed to have greater yield variation following a drought in 2016.

A machine learning algorithm was developed to define the borders of new and larger units of area to insure—we called these Agro-Ecological Zones (AEZs). We allowed the satellite and yield data to reveal those areas where yields naturally followed a normal distribution, thereby showing only one mean. We then used these areas as units of area insured, as long as the distribution's variance is not too large. The precipitation variable within the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) satellite dataset was used to generate AEZs.

The AEZs were validated through two approaches. First, the AEZs predicted average yields collected directly from the field during 2017 and 2018. Second, these AEZs predicted insurance payouts observed over the two previous years in Pula's policy portfolio.

The practical implication of the model is that, for regions currently covered by Pula in Nigeria and Kenya, the machine learning model reduced total costs of yield sampling for area-yield index insurance by about 43 percent. This represents a significant reduction when considering expanding the product nationwide.[5]

3 Data variables observed included precipitation, light reflection from the soil, and soil temperatures, among others. Satellite datasets used include CHIRPS, Sentinel, Lansat, and MODIS, which are all publicly available.

4 LGAs are areas of government administration that are traditionally used as the units of area to insure.

5 The cost savings in Nigeria was achieved by reducing the number of units of area insured from the current 22 LGAs insured to 5 larger AEZs. The number of yield measurements or crop cut experiments required for each AEZ to maintain current levels of basis risks and adequately predict past average yields and payouts is 75, versus the 30 used for each LGA. Therefore, the cost of yield sampling or crop cuts using AEZs is 5 zones x 75 crop cuts per zone x US$36 in average crop cut cost, resulting in a total of US$13,500. The current cost using LGAs as units of area insured is 22 zones x 30 crop cuts x US$36 unit cost for a total of $23,760. This represents a 43 percent reduction in yield sampling costs and number of crop cuts. In the case of western Kenya, without the use of AEZs, total yield sampling costs were US$37,800 (42 LGAs x 25 crop cuts per zone x US$36 per crop cut). In the same context, using the AEZ method, costs would be US$21,888 (19 zones x 32 crop cuts per zone x US$36 per crop cut)—a 42 percent cost reduction.

Each step in the analysis was explained to Pula's insurance and reinsurance partners, and their feedback was considered. Engaging with partners was critical because they underwrite the risk in the insurance policies issued by Pula. The partners agreed to use the AEZ model in western Kenya during the dry season (March to April 2018) and in north-central Nigeria during the wet season (May to June 2018). This decision indicated that they had confidence in the model. During this time frame, 62,692 smallholder farmers were insured by Pula in Nigeria, while in Kenya, 319,200 smallholders were insured.

Implications for practitioners and development actors

From this experience we learned that there are several ways to apply satellite data in the quest to scale smallholder agricultural insurance. In the context of the CGAP-Pula collaboration, we needed to learn from several approaches before finding the one that was feasible, given the market conditions where Pula, smallholders, and other commercial partners operate. The final approach used moved away from the initial goal of developing an algorithm that predicts individual farmer yields with satellite data to one that defines AEZs, or larger units of area insured, which translates into important operational savings for area-yield index insurance products. This approach is one of potentially several. Practitioners and development actors can adapt it to speed up innovative satellite data applications that improve efficiency and effectiveness within smallholder insurance markets.

It was also critical to engage, from the start, partner insurers and reinsurers during the analytical process to secure their agreement to incorporate the model in their own actuarial analysis. Without their buy-in, the potential for replication and scale of this model for agricultural insurance would be limited.

The experience taught us to be open to reformulating the initial analytical approach. It also taught us that access to satellite data itself may not be a persistent constraint. Recent innovations in satellite technology have enabled greater data quality and accessibility to the point where—as in the CGAP-Pula collaboration—access to the right satellite data for a given context may be free of cost.

Significant efforts and investments are still required to collect farm-level yield data that are not only accurate but also include lower yields faced by more vulnerable smallholders. These data are needed to develop sound index-based insurance models. Although providers would be wise to partner with private agribusinesses to collect yield data, they will also need support from government and other development actors to gain greater yield variability in data sets by sampling yields among smallholders who do not participate in more structured value chain schemes.

The approach developed by CGAP and Pula has already begun to enable partner insurers to serve more smallholders so that these farmers can protect their agricultural inputs and loans against shocks that are most relevant for them. Evidence from the literature suggests this can lead to greater resilience.

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