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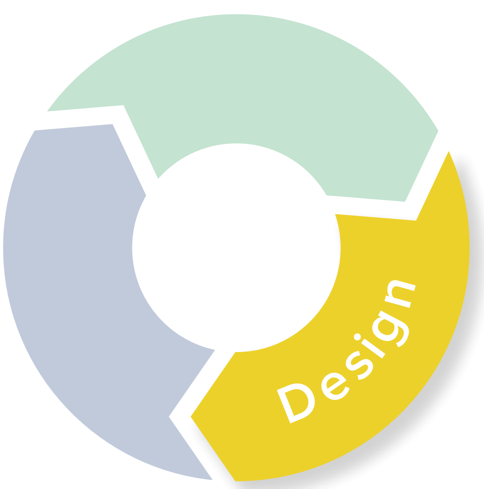

TOOLKIT:
AGRICULTURAL INDEX INSURANCE FOR DEVELOPMENT IMPACT

STAGE 2: DESIGN

USAID FROM THE AMERICAN PEOPLE
I4 INDEX INSURANCE INNOVATION INITIATIVE
BASIS
UC DAVIS UNIVERSITY OF CALIFORNIA

This resource is part of the Feed the Future Innovation Lab for Assets and Market Access publication series, *Agricultural Index Insurance for Development Impact.* The series will lead you through steps to **Assess** the viability of agricultural index insurance for a population and commodity, to **Design** a high-quality index insurance product and to **Scale** the intervention to have the greatest development impact.

This series is part of the AMA Innovation Lab's Index Insurance Innovation Initiative (I4) at UC Davis, which since 2009 has led research and development on high-quality agricultural index insurance interventions worldwide. Learn more: basis.ucdavis.edu/index-insurance-innovation-initiative-i4.

This resource was made possible by the generous support of the American people through the United States Agency for International Development (USAID) grant AID-OAA-L-12-00001. The contents are the responsibility of the Feed the Future Innovation Lab for Assets and Market Access and do not necessarily reflect the views of USAID or the United States Government.

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INTRODUCTION

At its most basic, insurance benefits farmers by moving money across time from when they have money to when they need money the most to cope with shock. There are other ways to move money through time, like savings, but unlike savings, insurance payouts depend on a covered shock, not on how much a farmer has already put in.

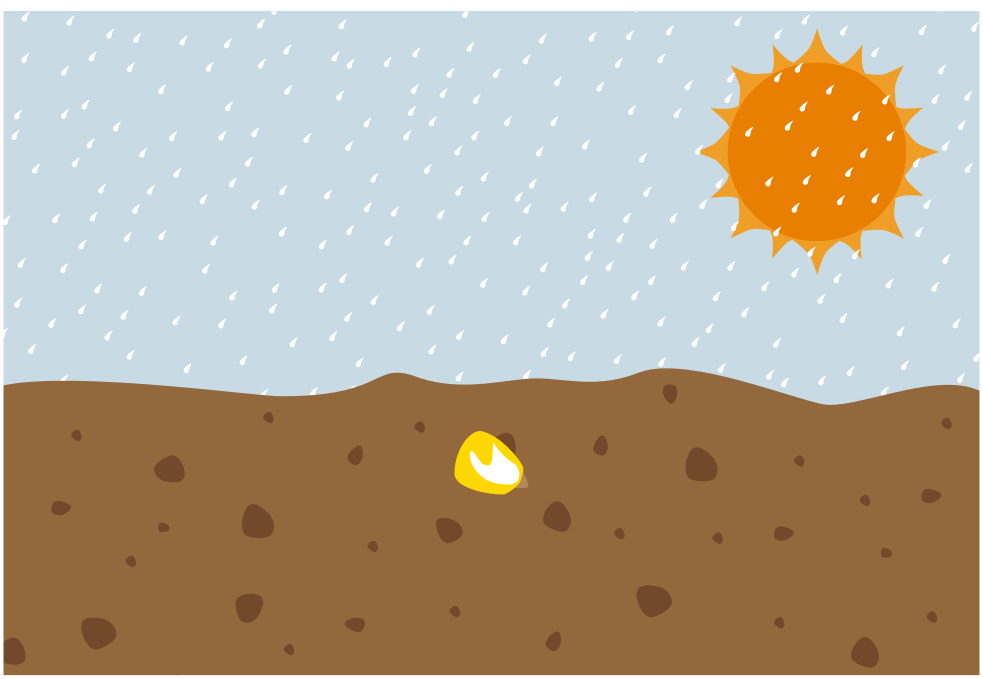
For our purposes, contract quality is not only determined by whether the index triggers payouts when it's designed to, such as when rainfall falls below normal. Quality means the insurance can effectively move money across time from when farmers have money to when they most need it.

Stage 1 of this toolkit summarizes how agricultural index insurance works and some key considerations to evaluate whether it might fit your development objectives. **Stage 2** zeroes in on the components needed to build a high-quality index insurance product that meets two key criteria:

1. For your chosen area and commodity, weather-related risk is shared by enough farmers that an index-based product can cover a significant share of losses
2. Basis risk can be minimized enough through product design to effectively protect farmers when insured events occur

Steps in Stage 2

1. Choose an appropriate Index
2. Get index and crop data
3. Address index failure
4. Bundling to expand impacts



Throughout this stage of the guide are icons that represent three of the key ingredients required for a high-quality agricultural index insurance product. Soil represents shared risk among farmers in an area. The maize seed represents an index that accurately estimates losses. The rain and sun represent high-quality product design.

It may be useful at this point to contract out for advanced technical expertise, though it is helpful to understand how a high-quality index insurance product is built from the ground up.

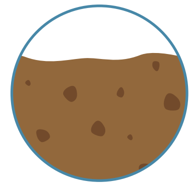
By its very nature, index insurance will always contain basis risk, which is the chance that an index will fail to trigger for actual individual losses. One source of basis risk is idiosyncratic risk, which is risk an individual farmer does not share with neighbors. This could be unique geographic features that make a farmer's land more or less susceptible to drought or flood. It could be a risk of injury, fire or other random occurrences that compromise productivity.

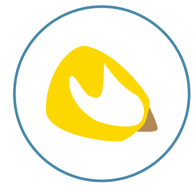
The other source of basis risk is "design risk." Design risk is the chance of failure built into the product itself. One example is an external measure—such as measurements of rainfall—that may fail to predict an area's actual average yields. In this case, a product that triggers for a lack of rainfall may still have failed if there have been no actual crop losses.

Basis risk for an index insurance contract can never be completely overcome but can be minimized though effective contract design. Whatever the source of basis risk, if the index fails to detect an insurable event, the insurance is little more than a lottery ticket and is unlikely to have a development impact. If the insurance fails to trigger a payout when farmers experience a significant loss from an insured shock, it will actually leave them worse off than if they had not bought insurance at all.

While **Stage 2** of this toolkit is not a technical guide, it explains important, basic concepts that development professionals and technical experts can use to choose an appropriate index and to evaluate whether a potential product can offer both high quality and high value to farmers. As in all interventions, it is important to ensure that at a minimum we do no harm.

STEP 1: CHOOSE AN APPROPRIATE INDEX





The quality of an index insurance product in large part depends on how well historic yields match an index, such as vegetation growth, rainfall or average yields in an area. These are only three of many different kinds of indices (plural for "index"), but two key criteria an index must satisfy are:

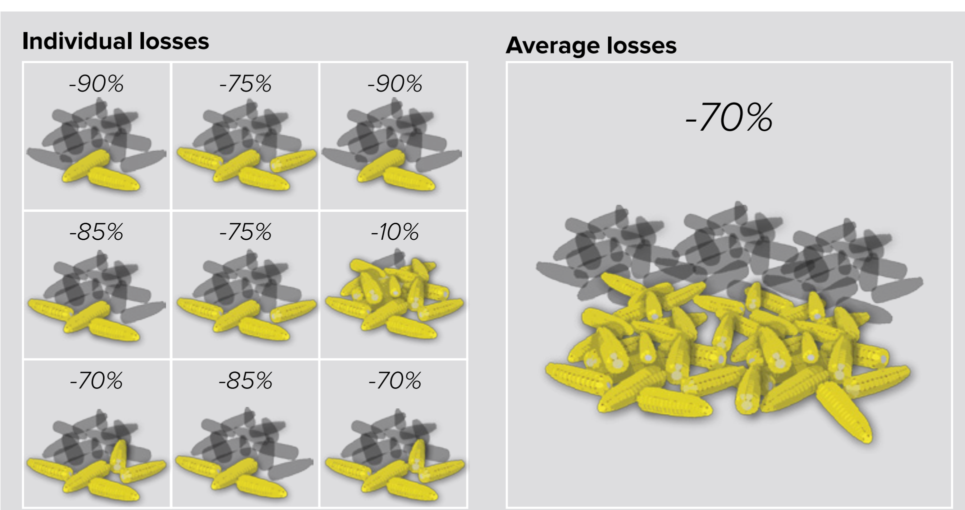
1. It cannot be manipulated by either the insurer or the insured
2. It is independently verifiable and transparent

This step summaries the most common indices used to build insurance for small-scale agriculture in developing countries. Not all of these will be appropriate for your population and commodity. This step would be a good time to rigorously test your estimations of insurability and potential impact from **Stage 1**, Step 5.

Area-yield Index Insurance

An area-yield index uses the average yield in an area to calculate payouts for insured farmers in that area. Theoretically, this index should be the best at predicting individual yields. Unlike measures that only estimate yields, this index is based on a direct measurement. An area-yield contract is an ideal index insurance because the only uncovered risk comes from variation in individual farmer yields compared to the area's average yield.

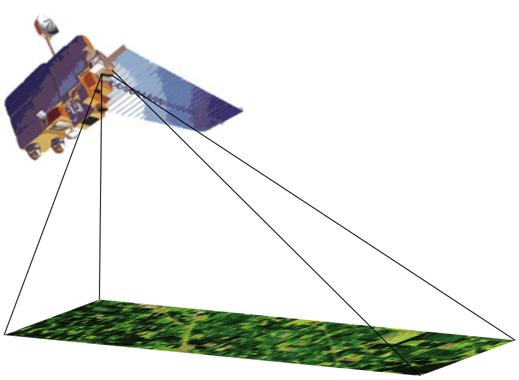
Despite this lack of design risk, an area-yield product might not be feasible in



While individual farmers in an area may experience a range of losses, an area-yield product pays out equally to each covered farmer based on the average losses in the area.

By comparing average and individual losses, you can quickly learn whether the amount of shared risk is so low that no index-based product is likely to produce development impact or sustainable demand for the product.

You can also use an area's historical average yields to benchmark the predictive power of an index built with remote-sensing data like a satellite-based index.



The MODIS instrument aboard NASA's Terra satellite measures average vegetation cover across pixels of 250 m^2. Though this resolution could miss variation in conditions within that area, these measurements can still be used to accurately estimate crop yields.

practice because of the need for a timely measurement and reporting of yields. This may require expensive crop cuttings that add to the cost of insurance premiums, though where yield data is already being collected it can be a good option.

For example, in Ecuador, we tested a product using yield data collected in an annual national survey. In Burkina Faso and Mali, average yield data was already available because a single cotton company purchased all the cotton grown in the insurance zones. In the Kenya Crop Insurance Programme, the Government of Kenya already funds crop cuttings for use by anyone to build an area-yield insurance contract because they view the data as a public good.

In any case, yield data must be timely. Otherwise, payments may not reach farmers who most need them after suffering severe losses, compromising the contract's development impact.

Pros

- ✓ A measure of actual losses rather than an estimate
- ✓ Avoids high costs of verifying individual crop losses

Cons

- X Crop cuts to measure area yields can be expensive
- X Poorly timed measurement data can delay payments for losses

Satellite-based Indices

A number of indices for agricultural index insurance are based on measurements taken remotely by satellite. These measurements have a number of advantages over weather stations or other ground-based sources. One is their objectivity. They cannot be manipulated either by an insurance company or group of farmers. Another is their accuracy, which increases with the improvement of satellite technology. Also, satellite data is commonly free and publicly available.

National space programs are a primary source for data to build insurance indices. A number of the AMA Innovation Lab's insurance indices rely on the multi-national NASA Terra satellite which carries instruments that provide a variety of measurements of conditions on the ground. The European Space Agency and other national space programs also make their data freely available.

The variety of insurance indices that can be built with satellite data are growing rapidly with the advancement of satellite technology and research in the plant sciences. The indices we describe below are two prominent examples.

Normalized Difference Vegetation Index (NDVI)

The most common satellite-based measure for index insurance is Normalized Difference Vegetation Index (NDVI), which distinguishes vegetation from dirt or water and gives a measure of plant health based on the sunlight reflected from its leaves. Just like an image on a computer monitor, NDVI measurements are made up of pixels. After processing, a single pixel is represented with a number for the average amount of reflected light inside it.

Many products based on NDVI have proven to be high quality in certain contexts. NDVI is used to build the index for the successful Index-based Livestock Insurance (IBLI) program in Kenya, which has been adopted by the national Kenya Livestock Insurance Program (KLIP).

Gross Primary Prediction Index Insurance (GPP)

Gross Primary Prediction (GPP) is a satellite-based measure that estimates plant biomass production, which is closely related to grain production. This type of index can be incredibly accurate, but even satellite-based measures at the cutting-edge of index insurance design cannot solve every problem.

We tested GPP in both Nepal and Tanzania and found radical differences in its ability to estimate rice crop losses. In Tanzania, GPP could predict yields well. In Nepal, monsoon cloud cover during the growing season degraded GPP data to the point it could not be used to create a high-quality index. In Nepal, an area-yield was the most accurate way to estimate crop yields.

Pros

- ✓ High accuracy compared to ground-based measurements
- ✓ Objective and tamper-proof
- ✓ No-cost, public datasets are widely available

Cons

- X Adds design risk to a contract because the index will not perfectly estimate average losses.
- X Pixels used to predict crop yields may contain significant variation

Rainfall Index Insurance

Though some of the earliest index-based agricultural insurance products were based on rainfall, we do not recommend rainfall index insurance products. Rainfall index insurance uses measurements of rainfall from weather stations on the ground or from satellite. If rainfall in an area falls below a certain pre-determined level based on a rainfall history, then the index triggers an insurance payout.

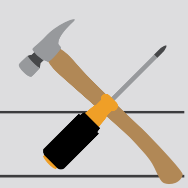
This contract has the advantage of simplicity, which may make it easier to explain to farmers unfamiliar with index insurance. However, broad experience with rainfall measures show that this kind of index is not very effective at estimating losses, which puts farmers who purchase coverage at risk if the index fails.

One reason a rainfall index is likely to fail is that the measurements taken at one location are less accurate as a farm's distance from that location increases. While farmers near a weather station may have the predicted rainfall, farmers far away might not. The number of expensive rainfall stations required for a fairly accurate index could be huge and still might not consistently predict crop losses. This does not include that weather stations require regular maintenance and frequently fail.

Rainfall in itself can also affect farmers much differently depending on topographic differences between plots. For example, farmers at the top of a hill may be fine with heavy rain while farmers at the bottom may lose their entire crops to flooding. In many countries, rainfall or snow in one region dramatically influences the outcomes in other areas, even those nearby.

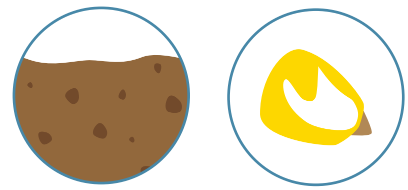
Satellite measurements of rainfall and the even more inclusive "weather-based" contracts that include temperature, wind speed or other factors can still fail. Satellite measurements address proximity and topography but weather it is still only one factor that determines losses.

Index ranking for testing:



1. ________________________
2. ________________________
3. ________________________

STEP 2:
GET INDEX AND CROP DATA



To create an agricultural index insurance product requires two types of data. The first of these is index data. The second is a history of yields or livestock losses at the highest granular detail. Historical yields going as far back as possible will help to capture annual variations, including shocks. The further back, the better.

Index Data

If your index is remotely sensed, as with satellite measurements, you should choose what the source of your data will be. For satellite measurements you can test multiple datasets from multiple sources.

As you consult with experts to design your insurance product, you should keep in mind that datasets even from public space programs like NASA and ESA can vary in the level of resolution and frequency of observation. For example, ESA's Sentinel 2 mission satellites take measurements at a resolution of 3m and 10m up to every five days. NASA's Terra satellite takes measurements in 250m blocks at least every other day.

You will not be able to complete the rest of Stage 2 without adequate data to explore potential products.

Yield Data

The level of aggregation for this data—meaning the size of the area or number of households represented in each measurement—is critical. Using data at a district level may not produce a contract that can effectively protect farmers at the village level. This could be because average yields across a large area mask the wide variation in yields possible between individual villages. Seek the lowest level of aggregation possible.

To design an index-based product that reliably predicts actual losses for individual farmers, there are a number of factors to keep in mind with regard to data:

1. At a minimum several years of data are required for as many households as possible. The longer the historical data, the more realistic your estimate of climactic variation over time
2. If data are inconsistent or limited, interpret the results carefully and consider the potential for systematic inconsistency
3. Data could cover years that are much worse than a long-term historical average
4. If household-level data is not available, seek the lowest level of aggregation possible (village, district, etc.)

Ideally, we would rely on individual-level yield data from longitudinal household surveys. Information on the location of individual plots, assuming those do not change over time, would make it possible to connect high-resolution satellite data to individual farmer yields.

Additional data collection could include yield histories from individual farmers based on recall. Though not as reliable as long-term survey data, it could compensate for gaps or weaknesses in existing data. This kind of data collection is not overly expensive to collect. The AMA Innovation Lab has collected it for a pilot study for less than $25,000.

Having these two types of data will allow you to take the first step of determining whether an index-based product is appropriate. Compare an area's historic average yields with individual losses will show you how much risk is shared in an area, which will determine whether any index-based product is appropriate.

Agronomic Data

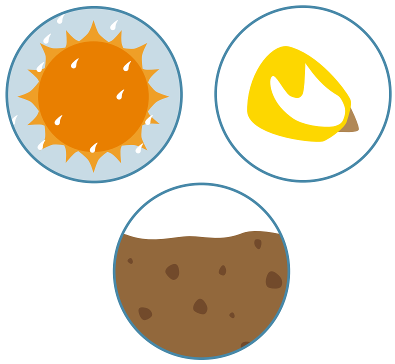
While yield data should be sufficient for an area-yield index, a remotely sensed index will also rely on some understanding of crop growth and development. For example, for maize there are periods that moisture is critical to its development, particularly around seed germination and grain filling.

If a remote measurement finds adequate rainfall during seed germination but is unable to measure conditions during grain filling, the index may fail to trigger despite catastrophic losses due to drought during that critical time.

Sources of data:

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________

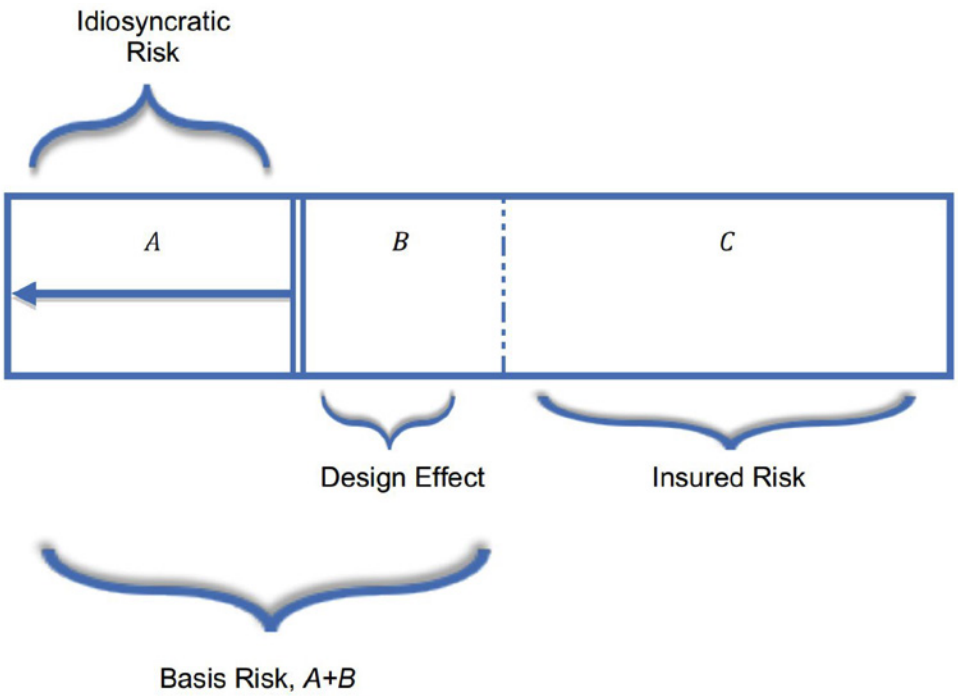
STEP 3: ADDRESS INDEX FAILURE



Every index insurance product will have a failure rate, however everyone has a common stake in developing quality products. Insurance companies risk their reputation if their product fails. On a large scale, even a handful of product failures can ruin index insurance markets for everyone, even those who offer high-quality products. If index insurance is publicly funded, low-quality products are a waste of limited resources.

Also, *when* a contract fails can make a big difference for individual families. If it fails when losses are particularly dire, the damage is even greater because the farmer will have lost the crop as well as the cost of the premium spent to buy insurance. This will be especially bad for a farmer who took out loans with confidence from being insured.

By definition index-based insurance will always carry basis risk. The goal is to reduce basis risk as much as possible both by choosing an accurate index and reducing the risk built into the contact design. Basis risk is simply any difference between what an index predicts across its given geographic area and the experience of an individual farmer in that area.



This diagram illustrates how index insurance is most effective:

- Idiosyncratic risk (A) is a small proportion of overall risk.
- Design effect (B) of the index minimizes the difference between the index and reality on the ground.
- Insured risk (C) is maximized.

Identifying Sources of Uncovered Risk

The size and composition of insurance zones can make a huge difference in any contract's performance. Even for an area-yield index, which removes design risk from a contract, the size and topographic composition of the insurance zone could determine the amount of variation in the area's measure of average losses.

Part of analyzing different indices is to estimate how much basis risk they build into a contract. In the case of an area-yield contract, which directly measures an area's average yields, the primary source of failure is when an individual farmer's yields are significantly different than the average. Adding a remotely sensed index, even an accurate one derived from satellite measurements, adds design risk to the contract.

For any kind of index insurance contract, you can define insurance zones to reduce variation between individual plots as much as possible. Insurance zones are defined geographic areas that contain enough similar households who all share common risks. Because index insurance only covers shared risks, take particular care to group households who share similar geography and environmental conditions.

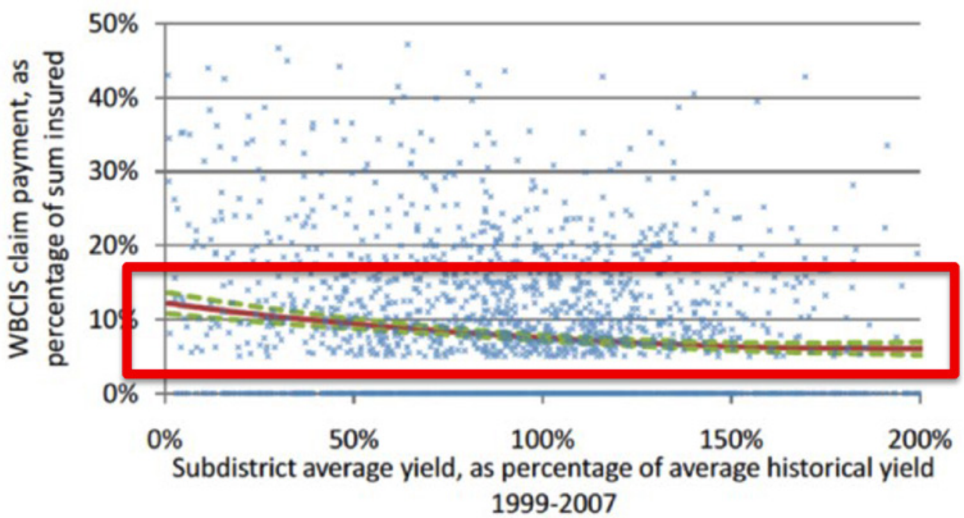
One way to identify how much shared risk there is among farmers in an area is to create a hypothetical area-yield product using the historical yield data you have already collected. Without significant shared risk, index-based insurance may not be a viable tool for achieving your development objectives and may in fact do harm.

It may also be that the area is uninsurable for that commodity, that the data are not detailed enough to build an effective contract, or that the biggest risk farmers face is individual as in the case of health shocks or other hazards.

When the AMA Innovation Lab tests our proposed index insurance contracts, we look for two key criteria. First, we use historic data from our selected index and yields to measure how often an index would fail to trigger payments in each insurance zone when farmers experience extreme losses.

Second, we establish the level of losses when an index is most likely to fail. While every index has a failure rate, a failure when conditions are most dire will do the most harm. This can also be a basic calculation that sets bounds based on a percentage of losses.

For example, how often would the index have failed to trigger payouts when farmers experienced an insurable level of losses? This information can be graphed on a scatter plot with a trend line to show exactly how the index would have



In this graph, the blue dots intersect at index insurance payouts compared to estimated losses (y-axis) and the average yield in India between 1999-2007. The average payout was roughly the same whether farmers suffered a total crop loss or had a crop that was double the historical average.

performed for each zone and each year.

A more precice approach would be to use a regression to calculate the correlation between yield and claim payment. Daniel Clarke from the World Bank conducted an analysis[1] of rainfall insurance contracts in India sold from 1999-2007 and found a correlation between yields and payments of -13 percent. This left contracts less likely to pay for losses than they were to pay as promised.

Improving Index Insurance through Contract Innovation

The goal of an index insurance product is to provide 100 percent coverage. In the field this is never possible. However, AMA Innovation Lab researchers have developed contract design innovations that reduce contract failures.

An audit rule allows farmers to request that their insurance company hire a third-party agronomist to conduct a yield audit to ensure the product has worked as it should. If the audit shows that the index failed to recognize losses at a level that should have been covered by the insurance, farmers receive the payouts they are due. This contract improvement can build trust in the product, and better provide security for vulnerable smallholder farmers.

In Tanzania, an AMA Innovation Lab pilot project put the audit rule into action.

[1] Clarke, D. et al. 2012. "Weather Based Crop Insurance in India." (March 1, 2012). World Bank Policy Research Working Paper No. 5985.

Despite a high-quality index that combined rainfall deficit measures with satellite detection, we estimated the contract would still fail to trigger for severe losses 13 percent of the time. Adding an audit rule to the contract provided farmers the added security needed to invest their limited funds in a more productive future. An accurate index is still critical with an audit rule. Frequent audits can easily raise the cost of insurance prohibitively.

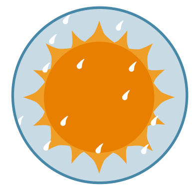
In practice, large insurance zones required by a reinsurer can lead to an increase in the contract failure rate for individual farmers. Farmers want the area to be as small as possible to maximize the likelihood an index will reflect their individual yields. Smaller aggregation reduces basis risk. For insurance companies and reinsurers, smaller aggregation also increases the potential for moral hazard in which farmers collude or manipulate conditions to trigger an unnecessary payment.

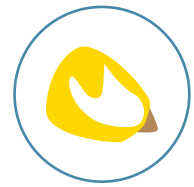
One way to overcome this tension is with a "dual-trigger" index that sets one trigger at a local level and a second trigger at a larger, multi-village level. This second trigger helps to prevent collusion as the area is too large, and payouts require both indices to trigger. This contract structure satisfies both insured and insurer while increasing contract quality.

We tested a dual-trigger index using historical yield and index data from Burkina Faso. In years of severe loss, a traditional single-index product would have paid the full insured amount only 30 percent of the time, lesser amounts 35 percent of the time, and would have failed completely the remaining 35 percent of the time. The dual-trigger contract would have paid correctly 85 percent of the time and failed only 15 percent of the time. Not only did this dual trigger make the contract agreeable to both farmers and insurers, it also increased the accuracy of the contract.

If you are concerned about your index's failure rate, try incorportating these two contract features. If neither of these features can improve quality, then stop. This index insurance contract is likely to do harm.

STEP 4:
BUNDLING TO EXPAND IMPACTS





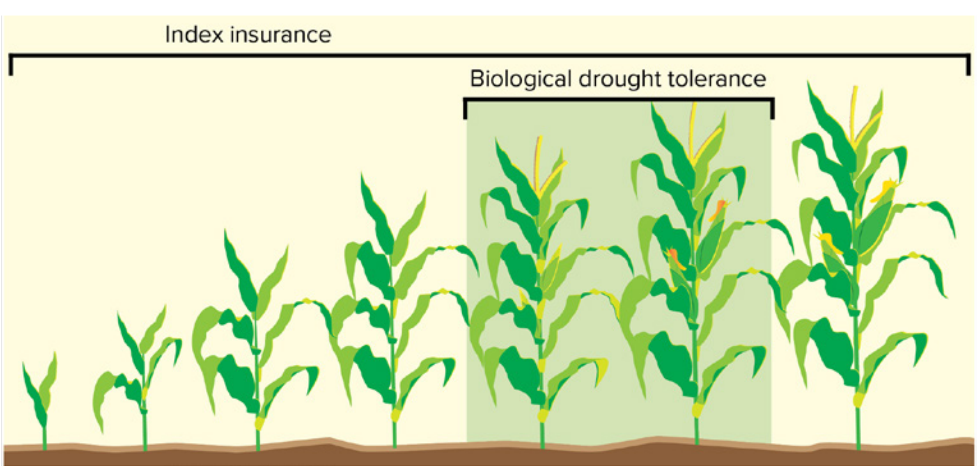
While a high-quality agricultural index insurance product on its own can be transformative for small-scale farming communities, the technology can also be bundled with other innovations that have the potential to magnify the impacts of both.

For insurers, bundling index insurance with other services or interventions accelerates outreach and penetration while reducing distribution costs. For non-insurance partners index insurance can reduce risk, build product loyalty or even generate an additional revenue stream. For farmers, bundling can increase access to insurance as well as access to credit and improved inputs.

Bundling can also be complex, and its success relies on the most complementary technologies or interventions. Its success also depends on the partners available in the area and the benefits they would gain. Bundling is not needed to achieve development impact with index insurance. If you cannot identify the right opportunity and set of stakeholders, do not proceed.

Bundling Index Insurance with Stress-tolerant Seed

The AMA Innovation Lab bundled index insurance with improved maize seed in Tanzania and Mozambique in partnership with CIMMYT and local insurance and seed companies. The index insurance was designed with NDVI data to trigger seed replacement in the event of crop losses, ensuring that farmers who purchased more expensive stress-tolerant seeds would be able to start the next season with those same seeds.



Bundling drought-tolerant seeds with index insurance for seed replacement

Drought-tolerant maize developed by CIMMYT is bred to withstand mid-season dry spells. Index insurance expands this protection to early season drought and full-season drought that can both cause drought-tolerant maize to fail.

effectively extended the drought protection built into the seeds. The guarantee the insurance provides also acts as an incentive for farmers who might not otherwise use improved seeds to try them.

The benefits come whether or not there is a bad year. In good years, farmers will benefit from higher yields generated by the improved seeds. In drought years, the seeds are more resilient and more productive than local seeds. In particularly severe drought years when even the stress-tolerant seeds fail, farmers receive seed replacements through the insurance.

The pilot in Tanzania has shown promising results with uptake and payouts. In 2016, 563 farmers across 30 villages bought the insured, drought-tolerant seeds. In the 2016-2017 season 2,001 packets (4,000 kg of seeds worth about US $8,000) were insured. That year, half of the villages received a payout due to early- and full-season drought. The network of seed vendors replaced 1,220 packets of seed as in-kind payouts.

Index Insurance and Microloans

In Ghana, an AMA Innovation Lab research team partnered with a microfinance lender to bundle drought index insurance with input loans. The team tested how payout beneficiaries, either the lender or farmers themselves, affected both access to credit and uptake. Insurance in which payouts go directly to lenders reduces the risk of making loans, allowing them to expand access to credit among smallholders and at lower interest rates, ultimately boosting technology adoption.

Farmers in all three groups applied for agricultural credit at similar rates (90-93%), suggesting the treatments had a minimal average impact on farmers' demand for agricultural loans. However, when insurance payouts would be directed to banks, they were 32 percent more likely to approve loans. This increase was for both men and women borrowers, though the likelihood of approval was 36 percent for men and 30 percent women.

Insurance and Contract Farming

Cotton farming in Mali and Burkina Faso offered a unique opportunity to bundle crop insurance with credit for agricultural inputs provided by the local cotton companies. These cases were unique in that these companies were the only cotton buyers in the area and they also provided, on credit, all the inputs farmers need to produce cotton.

The bundling leveraged a number of opportunities created by both contract farming and index insurance. The structure of contract farming and its reliance on regular and accurate yield measurement made it possible to build and test a high-quality area-yield index with a dual trigger even before it was deployed in the field. The insurance also created a way for farmers who lose crops to drought or other common risks to pay back their input loans and remain cotton producers.

The bundled index insurance had big development impacts in both Mali and Burkina Faso. In both countries, farmers invested significantly more in their crops. In Mali, where the project was halted before completion, farmers who purchased insurance increased their cotton planting by between 25-40 percent.

When drought struck in Burkina Faso during the 2014-15 season, the insurance stepped in as a safety net. Though the insurance payouts arrived late, farmers reported that the money made a big difference in their ability to sustain themselves until the next growing season.

The success of each of these projects was built through effective partnerships in which all stakeholders benefitted, particularly farmers. This was only possible because of careful analysis before launching the projects using many of the same concepts and strategies described in these steps.

In **Stage 3** of this toolkit, you will learn the essential components for establishing partnerships that can determine the success of your index insurance intervention, both in terms of development impacts and sustainable products.

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