Innovation Commission:
Climate Change
Food Security
Agriculture

THE UNIVERSITY OF CHICAGO

Improved Weather and Seasonal Forecasts[1]

1. Context

Farmers in low- and middle-income countries are increasingly vulnerable to weather uncertainty due to climate change. Weather uncertainty increases farmers' production risks. Climate change will exacerbate this uncertainty, with variation in daily precipitation increasing by 4-5 percent and temperature variability increasing by 10-15 percent per degree Celsius of warming (1, 2). Climate change is also making the timing of seasons more variable. This has major implications for regions dependent on a single rainy season for most of their annual rainfall, such as India and others affected by the South Asian Monsoon.

Farmers need short, medium, and long-range forecasts to optimize their agricultural decisions. Short-range forecasts (0-3 days ahead) are the most widely available and enable farmers to make day-to-day decisions like the timing of irrigation or the application of water-soluble fertilizer. Medium-range forecasts (4-10 days ahead) and long-range forecasts (ten days to one year) are less readily available and are relevant to strategic decisions such as crop and seed choice, area planted, and planting and harvesting date. This need for improved forecasting goes beyond just the timing of rainfall: low- and middle-income countries are also extremely vulnerable to inland and coastal flooding, heat waves, and extreme weather events caused by climate change.

The forecasts to which most farmers currently have access are insufficient. Forecasts produced in many low- and middle-income countries, typically by national meteorological departments, are often inaccurate, at the wrong time scale, or cover too broad of a geographic region, to inform farmers' management decisions (1, 2, 3, 4). This is partly due to limited weather observation data–which is an input to forecasts and enables assessments of accuracy–and limited coordination and data sharing across countries. Even with current weather observation data, better forecasts can be produced.

Most farmers in low- and middle-income countries currently lack access to reliable, high-quality, local forecasts. An estimated 260-305 million farms in South Asia, sub-Saharan Africa, and Southeast Asia stand to benefit the most from improved forecasting.

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[1] This is a draft document that will be updated periodically until the publication of the Innovation Commission final report

2. Improved Forecasts

New technology allows more accurate and timely forecasts, with large benefits for farmers in the context of increased weather variability. For example, new forecasts allow the timing of monsoon onset to be predicted over a month in advance. New technology also allows more accurate predictions weeks or even months in advance for broad characteristics of the weather due to better observation and research on regional or global phenomena driving local weather, like the El Nino-Southern Oscillation, and more accurate day-ahead forecasts in tropical regions.

Several public research institutes and for-profit firms now offer forecasts of improved breadth and quality. For example, the Potsdam Institute for Climate Impact Research now produces improved monsoon and rainy season onset forecasts for areas either not covered by any existing forecasts or only by coarse national forecasts, and with a substantial increase in lead time of up to six weeks. The Climate Forecast Applications Network produces a variety of forecasts, at several different time ranges (1-15 days, 16-40 days, and 2-7 months), offering several different weather parameters (rainfall, temperature, wind, and prediction of extreme events like cyclones), and with a resolution of either 18km or 36km. The Climate Hazards Center at the University of California, Santa Barbara (UCSB) provides daily 5-day, 10-day, and 15-day precipitation forecasts at a resolution of 5km across the globe.

However, these improved forecasts are not readily available to smallholder farmers. Global forecasting centers and many national meteorological departments are not tasked or financed to ensure their forecasts reach users in low- and middle-income countries. Forecasts are a public good that can be shared easily between end users. Hence, the private sector has a limited profit incentive to innovate to sell forecasts directly to the millions of farmers who need them.

Current forecasts often have limited accuracy due to limited observation stations. The Systematic Observations Financing Facility (SOFF) was launched in 2021 to help the countries with the biggest shortfall in weather operations expand their networks of weather stations. Investing in weather stations through the SOFF initiative could improve forecasts by allowing better assessments of accuracy as well as increasing the amount of historical weather data available for improved forecasts in the future. During SOFF's initial three-year phase, financing is needed to install and upgrade the highest priority 200-400 weather stations across 28 countries.

Longer-term investments could help improve forecast accuracy and strengthen systems for sharing data and delivering forecasts. Areas of opportunity for improved forecasting include better observation and research on regional or global phenomena (e.g., the El Niño-Southern Oscillation) driving local weather, which could lead to more accurate predictions weeks or even months in advance.

Public investment is warranted to improve the availability of high-quality forecasts in low- and middle-income countries. Forecasts are a public good in two senses. First, improvements in forecasting in one geography can help to improve forecasts in other geographies. As a result, governments have underinvested in collecting and sharing weather data and producing accurate forecasts because they do not capture the full benefit of these investments. Second, one user can share forecasts with another at zero cost while still retaining the full benefit of the information. As a result, each farmer is unwilling to pay the full value of the information, so the private sector lacks the profit incentive to deliver forecasts directly to farmers. Procuring and delivering improved forecasts at scale would enable sustained net social benefits to farmers that greatly exceed the costs, providing a strong justification for public support.

3. Impact and cost-effectiveness

Multiple studies find that farmers adjust their behavior and investment decisions in response to accurate weather forecasts. In Ghana, farmers in communities that received forecasts via SMS altered their planting and investment behavior, including farmers who received forecasts directly and those who did not. This suggests information about the forecasts spread among farmers in the same communities. In India, farmers who were randomly assigned to receive digitally-distributed weather forecasts substantially altered their planting and investment decisions to better align with the forecasted seasonal timing: farmers who had expected a shorter season than what was forecast increased their land under cultivation, added new crops and invested 34 percent more in all pre-harvest expenditures (Burlig et al. preliminary results).

Procuring and disseminating improved forecasts would have large benefits for farmers. For forecasts of the monsoon seasonal rainfall totals in India, the benefits of improving all state-level forecasts to at least the average level of accuracy would exceed USD 3 billion[2] for farmers over five years (estimation based on Rosenzweig and Udry 2019). Similar benefits are

[2] All values adjusted for inflation and standardized to 2023 USD.

found for short-range forecasts. In Benin, when farmers received forecasts over SMS, a randomized evaluation estimated benefits of USD 104-356 per farmer per year (estimation based on Yegbemey et al 2023). A randomized trial of disseminating weather forecasts and price information by SMS in Colombia found labor savings of USD 103-280 per farmer per year–although this result is imprecisely estimated (estimation based on Camacho and Conover 2019). These studies include a wide range of different types of forecasts, agricultural decisions, geographies, crops, delivery channels, and methodologies, so significant heterogeneity is to be expected. However, all these studies show positive impacts and present a realistic range of the potential benefits of forecasts in various settings. Forecasts also have large impacts on increasing resilience to disasters and improving health (1, 2, 3, 4).

The benefits of procuring and delivering improved weather forecasts outweigh the costs by orders of magnitude. Improving monsoon onset forecasts in India has estimated benefits of USD 3 billion (estimation based on Rosenzweig and Udry 2019). The cost of procuring these weather forecasts could be as little as USD 5.6 million over five years, based on conversations with forecast providers. Activities to deliver forecasts more widely would have additional costs, but also additional benefits.

4. Potential for further improvements

Improvements in weather observation will have a greater impact if coupled with country agreements to share data generated from weather stations. As many weather systems are larger in scale than individual countries, data from one country benefits forecast accuracy in others, while limited coordination and data sharing hinder forecast system improvement. Building on the successful model of the World Meteorological Organization (WMO), investments that release data and forecasts into the public domain are likely to have spillover benefits for other forecasts, in addition to their direct benefits.

An online data-sharing platform could facilitate greater coordination, and improve forecasts. The WMO's global Climate Services Information System (CSIS) is one example. Such a platform could act as a public portal for users, including forecast providers, researchers, and "boundary organizations" that bridge between forecast providers and end users. This platform could host past, present, and future weather data to allow users to produce, deliver, and validate improved forecasts.

A standardized system for evaluating forecast accuracy would improve transparency and incentives for producers and facilitate procuring better forecasts. Additional research to identify where and under which conditions existing forecasts are already performing well would build on the existing work of the International Research Institute for Climate and Society (IRI) and the European Centre for Medium-Range Weather Forecasts (ECMWF)]. The results would identify "forecasts of opportunity" where existing forecasts can be used immediately, as well as establish the standards for external validation of forecasts. This system could be housed within the WMO or another similar organization. The results of this validation and research should be made publicly available so that they can be used by governments and other stakeholders when deciding which forecasts to procure and deliver in their geographies.

5. Potential for scale

Two-hundred-six million smallholder farming families who would benefit most from improved forecasts live in six countries affected by the South Asian Monsoon (estimation based on Leow et al., 2023)--Bangladesh, India, Indonesia, Pakistan, Thailand, and Vietnam--and six countries affected by the East and West Africa Monsoons--the Democratic Republic of the Congo, Ethiopia, Kenya, Nigeria, Tanzania, and Uganda. Procuring improved forecasts of monsoon onset timing for these 12 countries would cost about USD 23 million over five years, based on consultations with several improved forecast providers. Forecasts of other weather features, like rainfall amounts or temperature, at different timescales, (from days to weeks ahead of an event), could be produced by other forecast providers at similar costs. These forecasts could be prioritized based on the identified needs of farmers and the corresponding forecast aspects that would maximize benefits. In some cases, such as for monsoon onset, scaling access to improved forecasts could be done at a very low cost. Because monsoon onset forecasts are a topic of wide public discussion, relatively light-touch dissemination approaches could allow high-quality forecast information to spread widely. In other cases, weather forecasts could be delivered at relatively low cost using digital platforms via SMS and other channels.

Farmers demand high-quality forecasts. In India, 86.5 percent of farmers who were offered an improved forecast of rain onset accepted the offer and valued forecast access at USD 1.22 on average, far more than the cost of delivering it at scale (Burlig et al. preliminary results). This valuation is likely to be an underestimate of the forecast's true value since farmers can share forecasts for free with other farmers.

With the right technical assistance, national governments can facilitate the delivery of forecasts to the hundreds of millions of people who need them. Many governments already facilitate the delivery of forecasts through various channels such as newspapers, radio, television, websites, and in-person agricultural extension. While these channels do not reach all farmers, there are potentially large benefits to delivering better forecasts through these channels. Technical assistance could focus on helping governments select the best forecasts for their settings, adapt and customize forecasts to users' needs, communicate probabilistic forecasts in a way that is easy to understand and interpret, supplement forecasts with actionable agricultural advice, optimize messages for frequency, timing, length, and complexity, and rigorously test and evaluate service delivery to inform how to scale most effectively. For example, technical assistance helped improve a governmental phone-based agricultural extension system in East Africa that has provided agricultural advice to more than 6 million farmers via interactive voice response (IVR). Changes recommended for the design of this system had substantial effects on the amount of information accessed by farmers.

6. Potential path forward

This section first discusses estimated investment costs for procuring improved forecasts for monsoon onset timing in India and procuring monsoon onset and long rains forecasts for a set of twelve countries, including India. Then, the section discusses the dissemination of improved forecasts. Finally, the section discusses a set of investments to improve global forecast systems.

Donors could support procuring forecasts to benefit 100 million farmers in low- and middle-income countries in Africa and Asia. Research institutes and for-profit firms already produce shovel-ready forecasts for some states in India for parameters such as the timing and quantity of seasonal monsoon rainfall. These could be replicated for the entire South Asia region and beyond at a relatively low cost.

RFPs for the provision of these forecasts should specify that both the forecasts and information on how the forecasts were constructed would have to be put in the public domain. This would be important to help ensure that forecasts could be improved globally over time and that costs remain low.

Procuring improved forecasts for monsoon onset for all of India would cost approximately USD 5.6 million over five years. Cost estimates are based on consultations with several improved forecast providers. More extensive due diligence with a wider range of forecast providers is needed to refine this cost estimate.

Procuring higher-quality forecasts for twelve countries (South Asian Monsoon onset forecasts in Bangladesh, India, Indonesia, Pakistan, Thailand, and Vietnam, as well as long-rains onset in the Democratic Republic of the Congo, Ethiopia, Kenya, Nigeria, Tanzania, and Uganda) would cost about USD 23 million over 5 years. Cost estimates are based on consultations with several improved forecast providers. More extensive due diligence with a wider range of forecast providers would be needed to refine this cost estimate.

Existing delivery channels could be used initially for disseminating improved forecasts, with expansion into improved digital tools over time. Forecasts could be delivered at scale through mass media channels such as newspaper, radio, and TV as well as through digital channels such as voice messages, SMS, and WhatsApp. Digital delivery may not be necessary for all geographies and forecast types. However, it could provide additional value by allowing customization to individual farmers' needs and providing forecasts at greater geographic resolution and frequency, especially for forecasts that vary across small geographic distances and with shorter time horizons. See [companion case on digital agriculture] for more on the potential of digital channels to deliver weather and other information to farmers at scale.

Several complementary investments could help improve global forecast systems to facilitate the production and procurement of better forecasts in low- and middle-income countries. These investments could be implemented over the next five years but are expected to deliver impact in 5-10 years. Budget estimates are preliminary and based on published budgets from SOFF, figures from Rethink Priorities, and consultations with other implementing organizations.

An investment of USD 14 million could support installing and upgrading 200-400 weather stations through the SOFF initiative to increase the volume and quality of weather data. The SOFF Terms of Reference have identified an initial three-year phase, during which results-based financing is needed for the highest priority 200-400 weather stations to be installed and upgraded across 28 countries.

An investment of USD 7-10 million could help strengthen the global Climate Services Information System (CSIS) or another similar platform to facilitate data sharing and coordination among stakeholders. This would support a team to manage this platform, standardize data shared through this platform, make it widely accessible, and enforce WMO regulations for data sharing.

To address the limited transparency of forecast accuracy, donors could support research to benchmark forecasts and a standardized system to validate forecast quality. An investment of USD 3 million could support g research to determine where and when existing forecasts are accurate in twelve low- and middle-income countries and a total of nine forecasts. Using that research, an additional investment of USD 9 million could establish a standardized, objective system for external validation of forecast accuracy (USD 9 million).