# Digital Agriculture[1]

**Digitally delivered services, including weather forecasts, advice on agricultural practices, and information about new crops and technologies, could have very significant benefits for farmers in the context of climate change.** These services have very low marginal costs, making them highly cost-effective. Governments are already providing digital services to farmers, but there is scope to improve and expand digital agriculture.

## 1. Context

**Changes in temperature, precipitation, pests, and agricultural markets due to climate change can reduce the effectiveness of traditional agricultural practices.** This increases farmers' need for new sources of information, for example, on weather, pests, new crops, and improved farming practices. Timely and accurate information can help farmers to adopt new practices, and mitigate losses from external shocks.

**Most smallholder farmers lack access to science-based agricultural information.** In part due to the cost of in-person extension, farmers often outnumber extension workers by more than 1000 to 1. Many extension programs have inadequate management and limited accountability of extension workers. According to a 2017 survey conducted in India, only 6 percent of farmers reported receiving advice from an extension agent within the past year, and 70 percent of farmers expressed distrust in the recommendations provided by extension workers.

## 2. Digital Agriculture

**Digital agriculture can inexpensively provide timely, science-based, and potentially customized information to farmers on topics such as weather forecasts, pest outbreaks and control, new seeds or other agricultural technologies, and soil chemistry**. Beyond directly providing advice to farmers, digital communications could help improve the effectiveness of in-person agricultural extension workers, link farmers to others facing similar challenges, and improve the efficiency of agricultural markets by linking farmers, input markets, cooperatives, contract farming organizations, and traders.

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

**Growing smartphone ownership can increase the effectiveness of digital agriculture.** Smartphone ownership is already high in many low- and middle-income countries and is forecast to grow rapidly over the next few years. In India, around three-quarters of rural households with children aged 3-16 own a smartphone. The widespread adoption of smartphones can be leveraged to enhance digital extension, including showing video demonstrations of agricultural techniques and providing more complex services to farmers, for example, by allowing farmers to take photographs of pests and receive personalized advice on them.

**Multiple organizations have experience implementing large-scale digital agriculture advisory services.** Government programs that have implemented digital agricultural extension include 8028 from the Agricultural Transformation Agency in Ethiopia, mKisan in India, Agronet in Colombia, MoA-Info in Kenya, the Extension 2.0 program in Punjab, Pakistan, and the e-Extension Program for Agriculture and Fisheries in the Philippines. Telecommunication company-supported programs include Connected Farmer from Safaricom in Kenya, Connected Agriculture Program for Punjab from Telenor, Pakistan Krishi Sheba from GrameenPhone, Tigo Kilim by Tigo in Tanzania, and Farmer's Club by Vodafone in Ghana. Non-profit organizations include iCow in Kenya, Esoko in Ghana, Acceso in Colombia, the Ethiopian Soil Information System, and Digital Green and Precision Development[2], which have implemented programs in East Africa and South Asia.

**Several governments have worked with technical partners to develop new digital advisory systems or improve existing ones.** For example, Ethiopia worked with technical partners and discovered that streamlining the registration process for their phone-based service increased the time farmers spent listening to the agricultural content by 18 percent. The Government of Punjab, Pakistan, collaborated with NGO Precision Development to enhance farmers' understanding and adoption of soil health card recommendations. They consulted farmers and leveraged human-centered design principles to redesign soil health cards and supplement them with explanatory phone calls. Technical assistance can also help governments deploy and scale digital agriculture services. In Odisha, India, an NGO worked with the government to design a digital extension service that the government later took over and expanded with public funds. The program now reaches over 6 million farmers.

## 3. Impact and Cost-effectiveness

[2] Michael Kremer discloses that he is a non-compensated board member of Precision Development, a nonprofit organization.

**Farmers adjust their behavior and investment decisions in response to accurate digitally distributed weather and seasonal forecasts.** In Telangana, India, farmers who received forecasts of monsoon onset via SMS updated their planting and investment decisions: farmers who had expected a shorter monsoon season than what the forecast predicted cultivated more land, added new crops, and invested 34 percent more in pre-harvest expenditures (estimation based on Burlig et al. preliminary results), while farmers who expected longer monsoon seasons than predicted adjusted toward the forecast in the opposite direction. In Ghana, farmers in communities that received weather forecasts via SMS optimized the timing of their planting and chemical application to align with forecast weather. This included both the farmers who receive forecasts directly and others in the same community, indicating that farmers who received digital forecasts shared them with others. In Pakistan, farmers who received 2-day weather forecasts via pre-recorded voice calls accurately recalled forecast information and changed their farming activities to be on days with more conducive weather.

**The benefits of delivering accurate forecasts to farmers are estimated to be orders of magnitude larger than the costs.** In Benin, a randomized evaluation found that SMS messages with day-ahead forecasts generated gross benefits of USD 104-356 per farmer per year in the form of increased yields and decreased labor costs (estimation based on Yegbemey et al. 2023). A randomized trial of disseminating weather forecasts and price information by SMS in Colombia found farmers saved USD 104-281 on labor costs per year, although this result is imprecisely estimated (estimation based on Camacho and Conover 2019). The cost of procuring weather forecasts varies, but at a sufficient scale could be well under $0.10 per farmer over five years.[3] The cost of designing and delivering messages could also be low. This suggests that benefits are hundreds or thousands of times larger than costs. Providing weather information with sufficient lead time for farmers to adjust their practices can reduce farmers' risks. Besides directly reducing farmer vulnerability, reducing risk for farmers also spurs investment.

**Climate change influences pest and plant disease conditions, and digital agriculture advisory can provide farmers with information on new pests and diseases and improve practices around pest and disease management**. Kenya's MoA-INFO system provided farmers with information on Fall Armyworm. In Gujarat, India, an automated voice message service increased the adoption of recommended practices for seeds and more effective pesticides by six percentage points among cotton farmers. In Ecuador, sending text messages summarizing Integrated Pest Management (IPM) practices increased the adoption of these practices by 7.2 percentage points among potato farmers who had attended an IPM training. Pest alerts can help farmers optimize input use. A blight alert system for potato farmers in

[3] Cost estimates are based on consultations with several improved forecast providers.

Bangladesh increased investment in fertilizer by 8 percent, which led to a 7 percent increase in yields.

**Farmers respond to soil chemistry information disseminated through digital extension.** East African farmers who received SMS messages—from One Acre Fund, Precision Development, and the Government of Kenya— were, on average, 22 percent more likely to adopt agricultural lime for acidic soils, albeit from a very low base, and were also more likely to use appropriate quantities of fertilizer. The program's estimated benefits exceeded marginal costs by 9 to 1.

**Digital agriculture may also have the potential to address nitrogen fertilizer overuse**. Nitrogen fertilizer overuse is common in some parts of the world, contributing to greenhouse gas emissions, reducing farmers' profits, imposing fiscal costs on governments subsidizing fertilizer, and damaging the local environment (1, 2). Governments in India and Pakistan dedicate significant resources to soil chemistry tests and disseminating findings to farmers via soil health cards. However, these cards are often difficult for farmers to understand. Digital agriculture can improve comprehension of soil health cards. In Gujarat, India, complementing soil health cards with audio messages and notes increased comprehension[4] by 37 percentage points from a base of six percent, which was equivalent to the impact of having an in-person discussion with an agronomist but much less costly.

**It will be important to ensure that soil health information disseminated to farmers is accurate, and a current limitation of soil health cards is that soil chemistry information in soil health cards is often not well correlated with nutrient levels observed in third-party testing.** Key steps for improving soil testing include incorporating better sampling and sample collection procedures, conducting third-party audits of a sample of soil chemistry tests, and using information based on spectroscopy.

## 4. Potential for Further Improvement

**The user base and infrastructure of digital extension can be leveraged to provide other agricultural services digitally.** Digital agriculture systems initially designed for extension could be used to deploy services that facilitate connections among farmers and extension workers, provide farmers with information on input suppliers, or link farmers with each other or with cooperatives or contract farming operations.

[4] Note, however, that a different research design in another part of India did not find that automated voice calls and text messages improved comprehension of soil health cards.

**Human-centered design could help ensure that content is relevant and actionable.** For example, human-centered design principles were used to redesign soil health cards in Gujarat, India, and develop complementary multimedia materials to better convey information to farmers. Similarly, in Ethiopia, identifying the obstacles farmers faced when using the hotline and conducting A/B tests to refine the service led to increased user engagement for an agriculture hotline.

**Machine learning tools and advances in artificial intelligence, such as large language models, could help adapt extension services.** For example, an experiment in India found that personalizing the timing of digital extension based on farmers' characteristics and past engagement led to a 2.6 percentage point increase in farmers' pick-up rate (an 8 percent increase over the baseline rate of 31 percent). With sufficient information on farmers, digital advisory services could be adapted for various crop choices, soil conditions, and educational background, and deliver specific weather forecast information based on farmers' geographical location. Substantial data will be needed to achieve this. This could potentially be collected through phone surveys, extension workers, or crowdsourcing directly from farmers, but cost-effective methods would have to be developed. Satellite data could also be used to provide location-specific information. Large language models could also enable farmers to engage with digital agriculture services in a more natural chat interface.

**In-person interventions based on behavioral science have shown tremendous impacts. These could potentially be adapted and delivered digitally, allowing them to reach many more people.** For example, digital agriculture platforms could substantially enhance post-harvest financial management, reducing the severity of lean seasons. Lean or hungry seasons, when food security consumption dramatically drops in the period before harvest, are a common phenomenon faced by many smallholder farmers in low-income countries. In Zambia, providing maize farmers with a simple infographic tool to remind them of future expenses that occur in the lean season increased savings by 15 percent. Farmers used the increased savings to self-finance additional farm inputs— labor and fertilizers—that subsequently increased their crop revenues by 9 percent. It may be useful to explore how digital platforms could provide similar tools to help farmers plan their future expenses.

**Promising tools that have demonstrated effectiveness in assisting farmers with long-term planning and investment decisions could be adapted for digital platforms.** In rural Kenya, an interactive intervention designed to raise aspirations and encourage long-term planning—through videos about successful local households and goal-setting activities—increased labor supply by 5 percent and investment in inputs by 22 percent. Similar effects among households in rural Ethiopia persisted five years after a screening of documentaries about real successful stories of local role models who moved out of poverty. In

Bolivia, dairy producers who participated in a similar aspirational hope training increased the use of quality-enhancing practices three months later. These tools could be adapted for digital delivery.

**Digital tools can help in-person extension services reach more farmers and communicate with them more efficiently**. Many extension workers already have smartphones, which they can use to share decision-support tools with farmers, show informational videos to farmers, look up information farmers need, and invite farmers to upcoming extension activities (1, 2, 3, 4). Developing a set of digital materials for extension workers could increase their effectiveness.

**Mobile phones can be used to improve extension worker performance.** When the Paraguayan government provided GPS-enabled cell phones to agricultural extension agents (thus allowing supervisors to monitor extension agents better), extension agent performance and farmer satisfaction improved. A rating platform for artificial insemination services provided by veterinarians in Pakistan increased provider effort and resulted in 25 percent higher insemination success for farmers without any change in prices paid. Evidence from the health sector suggests substantial gains from providing front-line workers with digital tools. For example, CommCare, an open-source mobile and web cloud product developed by Dimagi, provides near-real-time information about health worker performance. Equipping front-line health workers with CommCare improved prenatal care outcomes and reduced infant mortality, with an estimated social benefit-cost ratio exceeding 24:1.

**Digital services can also improve efficiency in markets, reducing price volatility.** A digital platform in Uganda linking traders with each other reduced volatility in agricultural markets by facilitating spatial arbitrage within the country. This can improve food security by helping insulate consumers against local shocks.

**Digital services can also improve supply chains in contract farming**. In Kenya, a hotline allowing sugar cane farmers to communicate with the company management reduced late fertilizer delivery by 23 percent and non-delivery by 54 percent.

# 5. Potential for Scale

**Digital agriculture provided by governments offers tremendous potential for scale.** The public sector has historically supported in-person agriculture extension; digital extension offers an opportunity for governments to expand their reach at a low cost. Digital agriculture programs led by governments have already reached large numbers of farmers in multiple countries, including Bangladesh, Ethiopia, Ghana, India, Kenya, Pakistan, and the Philippines (1, 2, 3, 4, 5, 6, 7).

**Subscription services, where farmers pay a fee to access digital extension services, reach only a small fraction of the potential market, creating a rationale for free provision by governments.** There may be a significant gap between the information's value and farmers' willingness to pay for it. Information is a public good because it is nonrival and nonexcludable. Farmers who don't subscribe to digital extension services can still access the information by speaking to subscribers, and purchasers can share the information with other farmers while retaining the information's full benefit. In addition, farmers may be unable to evaluate the quality of the information. This gap undermines incentives for the private sector to provide digital extension. These factors create a rationale for free public provision.

**Governments can digitally disseminate agricultural information at a low cost.** Cell phone towers in rural areas are often underutilized, so the true marginal social cost of sending additional messages is close to zero. As telecom regulators, governments could mandate that telecommunications companies offer public service announcement messages, particularly those related to national emergencies, such as weather disasters or pest outbreaks, at reduced rates or free of charge.

# 6. Potential Path Forward

**Digitally disseminating weather forecasts in India offers the opportunity to quickly reach large numbers of farmers and lay the foundation for further work in India and other countries.** India has experience rolling out digital extension services and a track record of maintaining these services. Odisha state worked with NGO Precision Development to build Ama Krushi, a digital extension program, which has now transitioned to state government operation. The government's mKisan platform, which was used to offer agro-meteorological data to farmers, has the potential to be expanded significantly using its database of over 100 million farmers. Digital weather forecast provision could also be an entry point to providing a wider set of digital agriculture services.

**Providing technical assistance to deploy digital agriculture services in six countries over five years is estimated to cost USD 13-20 million[5][6].** Technical assistance would include the following activities: i) identifying which forecasts to disseminate, ii) identifying additional digital agriculture services that could be provided alongside, iii) interviewing farmers and conducting focus group discussions to identify the most effective approach for conveying weather and agronomic information, and iv) supporting the government with dissemination, which would include identifying opportunities to refine the program, conduct A/B testing, and improve monitoring. These budgets cover the approximate cost of technical assistance needed to design, deploy, and refine these services in each country for five years. These estimates do not include dissemination costs, such as telecommunications fees[7]. Costs could be covered by donors, and potentially national governments, especially in the case of some middle-income countries. Across  Bangladesh, India, Ethiopia, Kenya, Nigeria, Pakistan, Tanzania, Vietnam, and Uganda, 383 million farmers could potentially benefit from digital agricultural services.[8] The next steps would be to understand where governments are interested in pursuing digital agriculture, where systems are in place to obtain lists of farmers' phone numbers, and where it otherwise makes sense to move forward.

**In countries that depend on a rainy reason for most of their annual rainfall, digital agriculture services could begin with the dissemination of high-quality seasonal forecasts.** Farmers in regions affected by the Asian Monsoon, such as Bangladesh, Cambodia, India, Pakistan, and Vietnam, as well as farmers in regions affected by the long rains in East and West Africa, including Ethiopia, Ghana, Kenya, Nigeria, Tanzania, and Uganda could benefit significantly from forecasts of rainy season onset.  Digital delivery would be particularly valuable for forecasts that vary across small geographic distances and require frequent real-time messages.

**The provision of weather forecasts can be an entry point for digital agriculture; this infrastructure can be leveraged to offer more complex digital agriculture services more broadly over time.** Disseminating weather forecasts is a promising entry point for digital agriculture at scale because of the large expected benefits for farmers. The infrastructure to

---

[5] These estimates are based on budget projections from Precision Development.

[6] This budget does not include the costs of procuring regional weather forecasts from global providers.. Weather forecasts are global public goods, and the Commission recommends that donors procure them and make them available to governments.

[7] The estimated telecommunication costs associated with sending 15 SMS messages per farmer per year for five years are USD 11.3M for India, USD 406M for Vietnam, USD 179.2M for Ethiopia, USD 117M for Pakistan, USD 84.2M for Bangladesh, USD 70.5M for Nigeria, USD 94.4M for Tanzania, USD 68.7M for Kenya, and USD 51.4M for Uganda.

[8] Cost estimates assume reaching 50 percent of farmers in each country.

support weather forecast dissemination (or other agricultural advisory services) could then be leveraged to provide more services to farmers, such as those described in Section 4.

**USD 10 million could create an open, tiered, evidence-based fund for innovations, including digital agriculture.** This would fund experimentation and innovation in digital agriculture–such as the potential improvements discussed in Section 4. The fund would be open to proposals from any entity, such as governments, NGOs, private companies, or researchers. The fund would be tiered to discipline spending decisions, with small grants to pilot early-stage ideas, medium-sized grants to test the most promising ideas, and large grants for scaling up only for innovations that have been rigorously tested and shown to be highly cost-effective. Development Innovation Ventures,[9] a social innovation fund at USAID, has a similarly open, tiered, evidence-based structure, and has yielded a high rate of returns.

[9] Michael Kremer discloses that he is the Scientific Director of Development Innovation Ventures.