A ROADMAP TO IMPACT AT SCALE:

the planet lab evidence toolkit

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Key Points:

FOCUS AREAS: The Planet Lab bridges the gap between research and policy with a thematic focus on promoting rural growth and prosperity and ensuring food systems' sustainability and resilience.

PARTNERSHIPS: It supports World Bank operations and government policies and has established knowledge partnerships with development partners like like the World Bank, GAFSP, UNICEF, FAO, WFP, and the European Union.

EVIDENCE TOOLKIT: The toolkit synthesizes lessons from over 15 years of work to provide evidence-based recommendations to guide project and policy design..

RESEARCH: The lab conducts impact evaluations across various countries in Africa, South and Southeast Asia, and Latin America and the Caribbean.

Key Lessons:

1. Design agricultural extension systems around the way farmers learn, in their local conditions.
2. Build flexibility into subsidy systems to maximize cost-effectiveness.
3. Support complementary interventions to realize the transformative potential of irrigation investments.
4. Combine short-term disaster response through rapid interventions with long term adaptations to foster climate resilience for vulnerable farmers.
5. Tailor support for value chains to their unique structures to improve farmers' market access and output prices.

In essence, the **Planet Lab Evidence Tool Kit** serves as a guide for practitioners and policymakers to design effective rural development programs that enhance agricultural productivity, promote sustainability, and build resilience to climate change.

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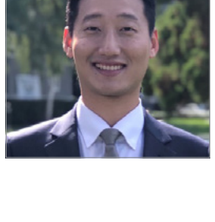

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The DIME Planet Lab

Agriculture is a crucial source of income and employment for rural communities worldwide. However, the increasing impacts of climate change pose a serious threat to millions of livelihoods, while food systems contribute to ecological degradation -- including biodiversity loss, water table depletion and contamination, and soil degradation. These twin challenges highlight the urgent need for rural development policies that enhance agricultural productivity while fostering sustainable and resilient food systems.

DIME's Planet Lab bridges the gap between research and policy, helping governments adopt proven solutions to meet these challenges and unlock opportunities for sustainable development. Since 2009, the Planet Lab has been working hand in hand with World Bank operations to support rural development policy, by integrating available evidence on what works best to meet farmers' challenges and generating new evidence where knowledge gaps persist. The Planet Lab generates this evidence through deep project and country partnerships that maximize the policy impact of its research program.

DIME's Planet Lab supports the World Bank's sustainable development operations by empowering practitioners globally to identify and test solutions and maximize learning spillovers. Through learning partnerships with World Bank operations and key development partners—the Global Agriculture and Food Security Program (GAFSP); the United Nations Children's Fund (UNICEF), Food and Agriculture Organization (FAO), and World Food Programme (WFP); and the European Union— the Planet Lab helps coordinate a shared agenda to strengthen the evidence base in priority areas.

The Planet Lab emphasizes two urgent research areas: promoting rural **growth and prosperity** and ensuring food systems' **sustainability and resilience.** Achieving these goals requires new technologies, improved land and water management, better-integrated value chains linking input and output markets, and strategies for responding to extreme climate shocks before they strike.

Within each research area, strategic work programs inform the design of essential interventions, and The Planet Lab leverages novel data tools and new data ecosystems to rapidly test their impact at scale. Through an iterative learning process, The Planet Lab delivers a body of knowledge to guide project and policy design that is greater than the sum of its parts.

In its newest efforts, The Planet Lab is ensuring that this knowledge base systematically feeds back into project design. To support this goal, The Planet Lab *Evidence Tool Kit* synthesizes the main lessons for over fifteen years of work. While it does not systematically aggregate evidence, this tool kit is intended to encourage governments and development partners to adopt proven solutions and iteratively test and generate new ones.

The Planet Lab partners with governments and development partners worldwide on a portfolio of over 70 impact evaluations in 30 countries spanning Africa, South and Southeast Asia, and Latin America and the Caribbean.

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The Planet Lab Evidence Tool Kit

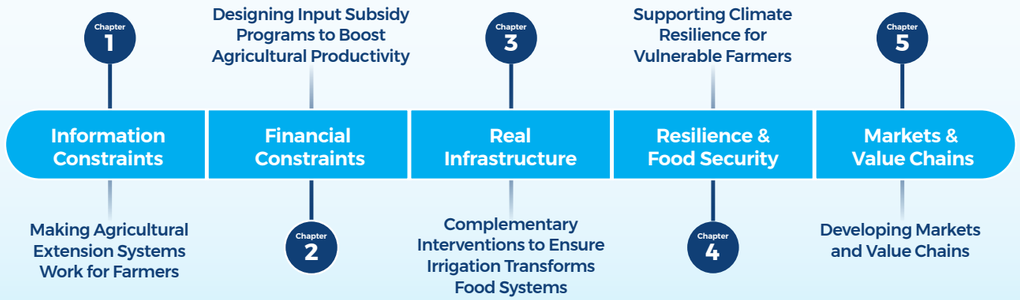
The Planet Lab Evidence Tool Kit provides practitioners and policy makers with actionable guidance for designing rural development programs and policies with higher impacts and higher returns on investment. The toolkit distills evidence on different dimensions of program design into targeted recommendations for programs and policies that promote rural prosperity and help build sustainable, resilient food systems in the face of climate change. They are based on a deep review of the most recent and rigorous evidence, including many DIME engagements with large-scale government investments.

The focus of each chapter in the toolkit is guided by the pipeline of upcoming joint World Bank-government investments in the agriculture sector. In dollar terms, the agriculture investment portfolio focuses the most on extension services, input subsidy programs, irrigation and value chain investments, and emergency response. The toolkit chapters are organized around these core themes (see Figure 1).

By maximize the effectiveness of investments in these areas, we can affect returns to large amounts of development finance. For example, letting farmers gain firsthand experience with a new flood-resilient seed variety can *double* the effectiveness of extension services—and the World Bank invests over US$900 million in extension services through the Africa Region Food System Resilience Program alone. This is the type of knowledge that can help deliver greater impact at scale.

New trial-and-adopt evidence will continuously feed into the toolkit, keeping it dynamic and ensuring that the latest insights to transform rural development are immediately shared at scale and leveraged in the operational pipeline.

FIGURE 1 - **The Planet Lab Toolkit overview**



The Five Key Lessons

1

Design agricultural extension systems around the way farmers learn, in their local conditions. This can make the difference between fast and slow diffusion of new technologies. It is difficult to train all farmers living in remote rural communities directly. This means that extension systems should be designed to 1) support how farmers learn and make decisions about early technology adoption, which will depend on the technology, and 2) maximize the local diffusion of knowledge beyond those directly targeted by programs (Kondylis et al. 2017). Evidence from Bangladesh shows that tailoring extension services to the type of technology being promoted can double the rate of adoption of productive and climate-smart technologies (Kondylis et al. 2023).

2

Build flexibility into subsidy systems to maximize cost-effectiveness. Despite the existence of profitable agricultural technologies, such as improved seeds and fertilizers, adoption has remained stubbornly low, especially in sub-Saharan Africa. Subsidies are an effective way to boost investment in modern inputs (Carter et al. 2021), but their design must accommodate fiscal constraints and minimize the risk of market distortions. We estimate African governments could save US$1–2 billion in fiscal space by moving from full to partial agricultural input subsidies. In Mozambique, moving from a blanket subsidy to a flexible eVoucher can increase cost-effectiveness by 20 percent. The digitally-managed eVouchers provide flexibility that enable a more flexible subsidy design that can balance between equity and efficiency objectives. Small packages promote self-experimentation among poorer farmers who have never used modern inputs, all the while getting larger farmers to self-target into larger packages that persistently generate impacts on productivity.

3

Support complementary interventions to realize the transformative potential of irrigation investments. Irrigation has the potential to transform the agriculture sector, doubling productivity and resilience in the context of climate change. Governments are making large investments in irrigation infrastructure, yet adoption by farmers remains low, limiting the returns to additional investment. Complementary interventions and design choices are critical to make sure irrigation infrastructure delivers on its potential. For instance, development and rehabilitation of large irrigation schemes require upstream land market interventions to ensure that farmers intent on cultivating irrigated crops can access plots within the scheme while allowing others to continue subsistence cropping (Jones et al. 2022). Constraints will be context specific and subsequent coordinated phases of programming, e.g. focused on value chain development, can support the construction and then long-term utilization of irrigation infrastructure and maximize the returns to the overall investment.

4

Combine short-term disaster response through rapid interventions with long term adaptations to foster climate resilience for vulnerable farmers. Climate disasters and stressors—such as floods, droughts, and cyclones—are increasing in frequency and intensity, exposing farmers to higher risks. It is critical to understand how best to support farmers in adapting to and recovering from climate shocks. In the short term, urgent humanitarian relief may be needed to help vulnerable populations anticipate and recover from disasters like droughts, floods, and hurricanes. In the long term, we can help households reduce their climate vulnerability with new climate-resilient technologies and better forecasts of climate and weather events. One key approach is using forecasts to accelerate humanitarian responses immediately as a shock is predicted, instead of traditional post-disaster relief. In Bangladesh and Nepal, experimental evidence shows that providing cash transfers just before the onset of floods increased households' food security and improved psychosocial wellbeing in the weeks immediately after the floods, without any other change in the budget. Similarly, in the context of droughts, experimental evidence from Niger shows that shock-responsive cash transfers delivered early improved food security earlier than traditional lean season response.

5

Tailor support for value chains to their unique structures to improve farmers' market access and output prices. Agricultural production does not happen in a vacuum. Farmer investment choices are influenced by anticipated markets while profits are directly affected by available output prices. However, a careful assessment of existing value chains and local context will dictate which value chain interventions are most likely to be successful. For example, rural feeder roads in Rwanda reduced local transportation costs by 30%, thus increasing competition among intermediaries and strengthening local value chains. Quality certifications can help farmers conform with food safety standards and access international markets (Zavala et al. 2023; Bold et al. 2022; Saenger et al. 2014).

the planet lab evidence tool kit

Making Agricultural Extension Systems Work for Farmers

Extension services provide knowledge and support to farmers by introducing and diffusing productive agricultural technologies. Despite large investments in agricultural extension systems, however, access to expert advice is still lacking in most of the developing world. In many low-income contexts, it is difficult for extension services to reach farmers, who operate small farms in remote areas. High transportation costs and low extension staffing levels complicate the pro blem of how to diffuse information and foster technology adoption among farmers in these areas.

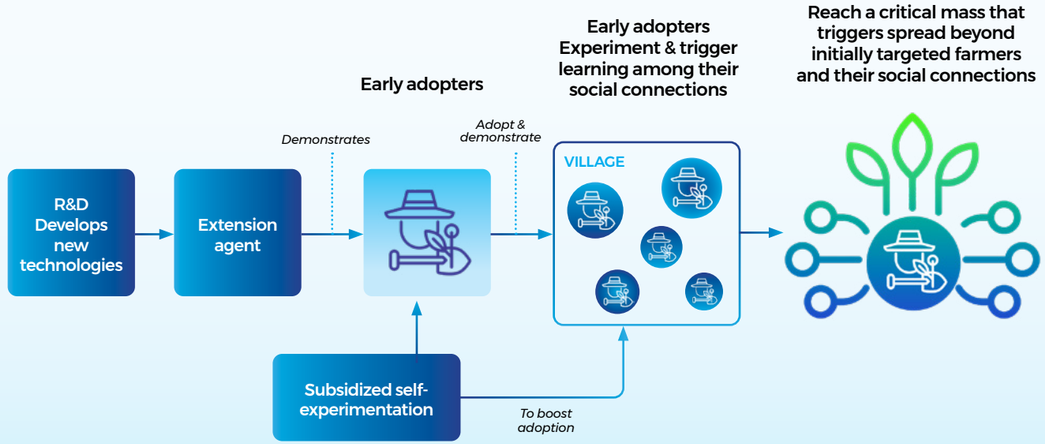
How can we design cost-effective extension systems that work for farmers?

This chapter presents a practical approach to designing cost-effective agricultural extension systems. We first propose a framework for decentralized knowledge diffusion among farmers that breaks technology adoption down into two stages: 1) the initial wave of technology adoption and 2) widespread diffusion in the community. We then offer actionable recommendations to maximize impact in both stages. These recommendations stem from a deep review of the literature on how to make extension services work for farmers, which we tailor to the requirements of distinct types of technology.

Opportunities for Impact

It is difficult to train all farmers living in remote rural communities directly. This means that extension systems should be designed to 1) support how farmers learn and make decisions about technology adoption and 2) maximize the local diffusion of knowledge. We break down the process by which rural communities learn about and adopt new technologies into two stages (See Figure 2).

FIGURE 2 — Extension framework



Initial wave of technology adoption (Stage 1)

Information about new technologies is brought to local communities through direct intervention. Extension agents are effective in directly training and transferring knowledge to farmers, as shown by a DIME impact evaluation with the Ministry of Agriculture in Mozambique.[1] At this stage, extension programs should focus on promoting adoption among a small number of farmers (lead farmers and other early adopters) by tailoring interventions to the kind of technology they aim to promote.

Widespread diffusion in the community (Stage 2)

Early adopters diffuse knowledge and promote technology adoption among a wider group of farmers, through demonstrations, self-experimentation, or both. Programs must incentivize demonstrations and self-experimentation so that information and technology spread beyond early adopters. At this stage, extension programs should focus on reaching a critical mass of early adopters in a community to trigger the further spread of knowledge through social networks**.**

How can we trigger an initial wave of technology adoption? (Stage 1)

Direct interventions are needed to bring information about new technologies to local communities. These interventions should be tailored to the type of technology being promoted because farmers need different kinds of information to decide whether to adopt different technologies. For example, farmers might need to learn about a technology's existence (What is it?), its application (How do I use it?), or its profitability (How does it benefit me?).

Different interventions are best suited to support learning about different types of technologies. For example, face-to-face demonstrations might be key to helping farmers understand a new *technique*. On the other hand, subsidies might be more effective in helping farmers self-experiment with a new *variety* of a known input, such as seeds, providing them with the most credible information about its returns. Interventions can be broken down into *centralized, decentralized,* and *combined* approaches (summarized in Table 1).

Centralized interventions

Face-to-face training from experts, like extension agents, is effective in increasing lead farmers' knowledge and adoption of a new technique (for example, pit planting or planting in rows), particularly when training includes hands-on practice.[2]

Decentralized interventions

Decentralized interventions, including minikits, input subsidies, and shared demonstration plots, promote self-experimentation by farmers—that is, they encourage farmers to learn by testing a new technology for themselves. These interventions are helpful when the new technology is similar to other, familiar technologies, so farmers learn about its returns rather than its existence or how to apply it.[3] Of these interventions, minikits generate more adoption than demonstration plots because farmers learn more from their own experimentation than others', as showcased by a DIME impact evaluation that provided flood-saline-resilient seeds to farmers in Bangladesh.[4]

To help decentralized interventions succeed, focus on getting the technology into the hands of as many farmers as possible and on allowing farmers to learn about the technology under varied conditions and during multiple agricultural seasons, because the gains from adoption depend heavily on weather, geography, and environmental factors (like pest breakouts). This is especially critical for technologies that aim to build farmers' resilience to shocks within a given crop system.[5]

Combined interventions

A combined approach is preferable when promoting a new input together with a new technique (such as promoting a new crop together with techniques for using the right amount of seeds, pesticide, or fertilizer). Combining centralized and decentralized approaches reinforces the impacts of each, as farmers are more likely to adopt a technology if they receive centralized training and test it themselves out on their own plots.[6]

TABLE 1 – Select learning intervention based on technology

Which Interventions Work Best for Different Types of Technology?		
TECHNOLOGY TYPE	**FARMERS NEED TO LEARN . . .**	**INTERVENTION**
New technique (for example, row planting or composting, applying fertilizer, or irrigation)	• About its existence • How to implement it	Centralized (for example, face-to-face training)
New variety of a familiar technology (for example, a new drought-resistant seed)	• About its existence • About its returns under varied conditions	Decentralized (for example, subsidized self-experimentation)
New technology requiring new technique (for example, moving to a new crop, such as from maize to tomatoes)	• About its existence • How to implement it • About its returns under varied conditions	Centralized + decentralized

1 Florence Kondylis, Valerie Mueller, and Jessica Zhu, 2017, "Seeing Is Believing? Evidence from an Extension Network Experiment," *Journal of Development Economics* 125:1–20.

2 Kondylis, Mueller, and Zhu, 2017; Benedetta Lerva, 2023, "The Monetary Value of Externalities: Experimental Evidence from Ugandan Farmers," *Policy Research Working Paper 10521*, World Bank, Washington, DC; Joshua W. Deutschmann, Tanguy Bernard, and Ouambi Yameogo, 2023, "Contracting and Quality Upgrading: Evidence from an Experiment in Senegal," Unpublished manuscript, last modified January 19, 2023; Kyle Emerick and Manzoor H. Dar, 2021, "Farmer Field Days and Demonstrator Selection for Increasing Technology Adoption," *The Review of Economics and Statistics* 103 (4): 680–93; Manzoor H. Dar, Alain de Janvry, Kyle Emerick, Erin M. Kelley, and Elisabeth Sadoulet, 2020, "Casting a Wider Net: Sharing Information beyond Social Networks," Unpublished manuscript, last modified July 20, 2020.

3 Michael Carter, Rachid Laajaj, and Dean Yang, 2021, "Subsidies and the African Green Revolution: Direct Effects and Social Network Spillovers of Randomized Input Subsidies in Mozambique," *American Economic Journal: Applied Economics* 13 (2): 206–29; Florence Kondylis, John Ashton Loeser, Mushfiq Mobarak, Maria Ruth Jones, and Daniel Stein, 2023, "Learning from Self and Learning from Others: Experimental Evidence from Bangladesh," *Policy Research Working Paper* WPS 10545, World Bank, Washington, DC.

4 Kondylis et al., 2023.

5 Kyle Emerick, Alain de Janvry, Elisabeth Sadoulet, and Manzoor H. Dar, 2016, "Technological Innovations, Downside Risk, and the Modernization of Agriculture," *American Economic Review* 106 (6): 1537–61.

6 Kondylis, Mueller, and Zhu, 2017.

How can we encourage widespread diffusion in the community? (Stage 2)

Reach a critical mass of early adopters to trigger the further spread of knowledge or technology in a community. In Mozambique, DIME worked with the Ministry of Agriculture to pilot a lead farmer model and found that, while the directly trained farmers adopted the promoted practices (Stage 1), the information did not spread to other farmers in the community (Stage 2).[7] Consider what incentives will encourage information sharing and self-experimentation.

To translate early adoption of a technology into widespread diffusion, extension programs can adopt the following approaches:

- Leverage *social learning* to increase the diffusion of knowledge.
- Address *complementary constraints* to adoption that farmers face.
- *Digitize extension* to multiply cost-effective diffusion.

Leverage social learning.

Once lead farmers have been introduced to a new technology, other farmers learn from them and diffuse knowledge through their social networks. However, this process can be slow.[8] Here are some ways to speed up the spread of knowledge.

- Because social connections are closer between farmers of the same gender, **ensure women farmers are trained directly** to encourage knowledge diffusion and technology adoption among other women farmers.[9]
- Rather than more intensely monitoring extension agents, **use performance-based financial incentives** to encourage lead farmers and other early adopters to promote and demonstrate the technology in their communities. A DIME impact evaluation in Rwanda showed that monitoring is not effective at increasing extension agents' efforts.[10]
- **Maximize the opportunities for farmers to gain firsthand experience.** This might mean spreading a demonstration technology (such as seeds) across as many farmers as possible, or supporting farmers in adopting a technique on their own plot. Although demonstrations on each individual plot will be smaller, the returns to firsthand experience are more important than the returns to the scale of the demonstration plot.[11]
- **Prioritize farmers who are centrally located, socially and geographically**, especially if technologies have positive spillovers (like pest control), because free-riding and collective action problems may slow the spread of information. Once information is available in a community, it will be in farmers' best interest to spread it: the more others adopt, the more each individual farmer benefits.[12]

7 Kondylis, Mueller, and Zhu, 2017.

8 Kondylis, Mueller, and Zhu, 2017.

9 Ariel BenYishay, Maria Jones, Florence Kondylis, and Ahmed Mushfiq Mobarak, 2020, "Gender Gaps in Technology Diffusion," *Journal of Development Economics* 143:102380; Florence Kondylis, Valerie Mueller, Glenn Sheriff, and Siyao Zhu, 2016, "Do Female Instructors Reduce Gender Bias in Diffusion of Sustainable Land Management Techniques? Experimental Evidence from Mozambique," *World Development* 78:436–49.

10 Ariel BenYishay and A. Muschfiq Mobarak, 2019, "Social Learning and Incentives for Experimentation and Communication," *The Review of Economic Studies* 86 (3): 976–1009; Erika Deserranno, 2019, "Financial Incentives as Signals: Experimental Evidence from the Recruitment of Village Promoters in Uganda," *American Economic Journal: Applied Economics* 11 (1): 277–317; Maria Jones and Florence Kondylis, 2018, "Does Feedback Matter? Evidence from Agricultural Services," *Journal of Development Economics* 131:28–41.

11 Kondylis et al., 2023.

12 Lori Beaman, Ariel BenYishay, Jeremy Magruder, and Ahmed Mushfiq Mobarak, 2021, "Can Network Theory-Based Targeting Increase Technology Adoption?" *American Economic Review* 111 (6): 1918–43; Lerva, 2023.

- Because farmers are more likely to share information they consider reliable, **use recognizable branding and communicate clearly and simply** to increase the chances farmers will pass on information they receive.[13]

Address complementary constraints.

Farmers often face more than one constraint to adopting a new technology, so addressing complementary constraints is generally effective at increasing adoption. Well-known technologies with heterogeneous returns are an important exception: in these cases, subsidized self-experimentation alone allows farmers to understand the returns to the technology on their own farms.

Complementary constraints can be addressed in many ways, and the most impactful combination of interventions will depend on the context. DIME is conducting a study in Mozambique to unpack the roles of financial and knowledge constraints. In close partnership with the United Nations Food and Agriculture Organization (FAO), DIME has designed an experiment in which farmers receive either agricultural training or input vouchers alone, or both interventions together. By comparing these groups of farmers, the study will estimate the relative effect of each constraint and the combined effect of both the training and the voucher programs.

Other policies that may complement extension include the following:

- Crop insurance to reduce the risk of investments
- Credit or subsidies to address liquidity constraints
- Savings accounts to smooth consumption and spur investment in new technologies
- Price premiums to address a lack of market demand for high-quality outputs
- Input certification if farmers mistrust the quality of inputs[14]

Digitize extension.

Digital tools can be powerful allies of agricultural extension:

- Given their low cost, digital services can greatly **improve the outreach potential of extension** by reaching underserved farmers or by reinforcing information through repetition.[15]
- Because digital services are likely provided by reputable organizations, they can **help overcome doubts about the reliability** of recommendations, ensuring a consistent, controlled message.[16]
- The flexibility of digital services allows extension programs to **tailor recommendations to local conditions** or sudden shocks and to **incorporate farmers' feedback**, boosting interest and demand for traditional extension services.[17]

13 Arun G. Chandrasekhar, Esther Duflo, Michael Kremer, João F. Pugliese, Jonathan Robinson, and Frank Schilbach, 2022, "Blue Spoons: Sparking Communication about Appropriate Technology Use," *NBER Working Paper* 30423, National Bureau of Economic Research, Cambridge, MA.

14 Dean Karlan, Robert Osei, Isaac Osei-Akoto, and Christopher Udry, 2014, "Agricultural Decisions after Relaxing Credit and Risk Constraints," *The Quarterly Journal of Economics* 129 (2): 597–652; Tessa Bold, Selene Ghisolfi, Frances Nsonzi, and Jakob Svensson, 2022, "Market Access and Quality Upgrading: Evidence from Four Field Experiments," *American Economic Review* 112 (8): 2518–52; Hope Michelson, Anna Fairbairn, Brenna Ellison, Annemie Maertens, and Victor Manyong, 2021, "Misperceived Quality: Fertilizer in Tanzania," *Journal of Development Economics* 148:102579; Deutschmann, Bernard, and Yameogo, 2023; Rocco Macchiavello and Josepa Miquel-Florensa, 2019, "Buyer-Driven Upgrading in GVCs: The Sustainable Quality Program in Colombia," *CEPR Discussion Paper* DP13935, Centre for Economic Policy Research.

15 Raissa Fabregas, Michael Kremer, and Franck Schilbach, 2019, "Realizing the Potential of Digital Development: The Case of Agricultural Advice," *Science* 366 (6471): eaay3038; Shawn A. Cole and A. Nilesh Fernando, 2021, "'Mobile'izing Agricultural Advice Technology Adoption Diffusion and Sustainability," *The Economic Journal* 131 (633): 192–219; Michelson et al., 2021; Tushi Baul, Dean Karlan, Kentaro Toyama, and Kathryn Vasilaky, 2024, "Improving Smallholder Agriculture via Video-Based Group Extension," Journal of Development Economics 169:103267.

16 Baul et al., 2024.

17 Jones and Kondylis, 2018.

Designing Input Subsidy Programs to Boost Agricultural Productivity

Without modern agricultural inputs, agricultural productivity will stagnate. Input subsidy programs are an effective way to increase investments in modern inputs, boosting productivity. However, poorly designed subsidy programs can result in market distortions while straining the government's limited resources.

How can we design, target, deliver, and complement input subsidies to minimize market distortions and maximize impact?

This chapter presents an evidence-based approach to designing and implementing input subsidies by looking at the key decisions that shape an input subsidy program. By considering the questions below, practitioners can identify opportunities to maximize the impact of input subsidies at each stage of program design (See Figure 3).

Opportunities for Impact

FIGURE 3 – **Considerations for input subsidy design**

Should we implement an input subsidy?

Yes if:

- There is a technology to increase yields or reduce volatility
- The baseline levels of adoption are low
- The technology is profitable at full cost, including the cost of the labor needed

How do we target?

How to target to support our goals?

EQUITY: Target poor and inexperienced farmers

OR

EFFICIENCY: Large, productive farmers?

Flexible e-voucher system can be used to reach both goals

E-vouchers digitally vary the subsidy level across input package sizes
--> meet the needs of both more and less experienced farmers.

How and when?

In-Kind versus voucher? It depends!

Are inputs already available in the local markets?

- *YES: vouchers may strengthen provision of inputs by private sellers.*
- *NO: subsidy through voucher redemption at a private seller may increase prices due to limited supply.*

Does timing matter?

Delays of expected subsidies may end up harming farmers

Is the subsidy alone enough?

What other constraints to input technology adoption exist?

Consider adding agricultural training, insurance, savings, and market-access interventions to address other constraints.

Will the subsidy's impact last?

How can the subsidy be made financially sustainable?

Experiment with different prices to get a sense of price sensitivity

When is it time to phase out the subsidy?

If the main constraint is lack experience, a one-time subsidy can have a lasting impact.

In the case of climate-resilient inputs such as seeds, farmers may need to experiment with the technology for several seasons to learn the returns.

Should we implement an input subsidy?

Implement an input subsidy when

- The goal is to improve agricultural productivity by increasing yields or reducing yield volatility,
- A productive technology has been tested and verified in the local context,
- The level of adoption of this technology is low, and
- The technology is profitable, even after accounting for the additional costs required for its adoption.

Input subsidies were traditionally used to encourage farmers to adopt improved seeds and fertilizers to increase agricultural yields. Now, in the face of climate shocks, it is also important to accelerate the adoption of input technologies that reduce yield volatility—such as drought-, flood-, and saline-tolerant seeds and crop or livestock insurance. Subsidies play a crucial role in increasing the adoption of these technologies, especially when farmers have limited experience with them and low confidence in their returns. Since their benefits may only become apparent after several seasons, creating incentives for farmers to experiment with these technologies is critical to convincing them to invest in the long term. Alternative policies, such as cash transfers, may be less effective than input subsidies at increasing the adoption of an input technology.

Determine the content of the input subsidy through local research and development, and promote input technologies that careful field trials have shown to be productive in a specific local context. Research and development for new agricultural technologies is heavily concentrated in industrialized countries, so inputs like improved seeds or fertilizers may not be profitable in different contexts.[18] For example, an experiment in Kenya showed that using too much fertilizer reduces its returns.[19] Moreover, uniform recommendations may not work well in contexts where agro-climatic conditions are heterogeneous and the types of nutrients needed vary across plots. In these cases, soil testing can be used to identify deficiencies.[20]

Consider the baseline level of adoption to determine whether a subsidy risks crowding out farmers' own investments. For example, an input subsidy program may increase the use of fertilizer, but beneficiaries may cut their own spending on fertilizer, effectively canceling out the effect of the subsidy on the overall amount of fertilizer used. On the other hand, in settings where the baseline level of adoption is low and there are a limited number of input sellers available, subsidies have little to no crowding-out effect on farmers' private investments.[21]

Consider the full cost of adoption when calculating the profitability of adopting a particular input technology, including the cost of complementary inputs needed to apply the input technology. While inputs like chemical fertilizer and pesticides can increase yields, they may not always be profitable because of their high cost and the cost of the labor needed to apply them. For example, an experiment in Mali found that free distribution of fertilizer tripled its use, increasing the value of production by 31 percent. However, the farmers receiving the subsidy needed to spend more on hired labor and herbicides, and the increase in production value did not offset these higher input costs.[22] If an input technology is not profitable, farmers may not invest in it once the subsidy is phased out, and adoption will not be sustained.

How can we target the subsidy to maximize its impact?

Deciding how much to subsidize inputs and who to target is key to maximizing the benefits of input subsidies and minimizing market distortions. Implementers should experiment with different subsidy values and rates to determine which ones yield the desired participant profile and mixture of inputs. It is also essential to recognize potential trade-offs between reaching the most vulnerable participants, maximizing the returns to input subsidies, and maximizing the number of beneficiaries within a fixed budget.

Not all farmers' returns to input use are equal.[23] One approach to determining subsidy eligibility is to target the poorest farmers; the other is to target the most productive farmers. Targeting the poorest farmers, who cannot afford inputs, can reduce inequality. While the subsidy may support their income, these farmers may have lower returns to the inputs than other farmers. Targeting the most productive farmers, on the other hand, maximizes the efficiency of resource allocation. These farmers may not be the poorest, but they may generate the highest returns per dollar spent on the subsidy.

Flexible e-vouchers reconcile these two approaches by allowing farmers to self-select into different subsidy options. Traditional input subsidy programs rely on predetermined subsidy levels and package sizes, while an e-voucher system can digitally vary the levels of subsidy as well as the sizes of input package. For example, a DIME study in Mozambique with the United Nations Food and Agriculture Organization (FAO) offered farmers three sizes of input package. Based on each farmer's selection, a corresponding subsidy value was transferred to an e-voucher card. The study found that smaller packages with a large subsidy rate promote experimentation among farmers who have never used improved inputs before. On the other hand, larger packages with a small subsidy rate are adopted by bigger, more productive farmers. This suggests that **self-targeting may reduce the fiscal burden of subsidies while increasing their overall returns**, by meeting the needs of both groups of farmers.

Community-based targeting, an approach to targeting that relies on community leaders and local knowledge, has been shown to be effective in identifying the most productive farmers. There are multiple types of community-based targeting to consider. Studies in Tanzania and Malawi show that community-based targeting can effectively identify farmers with the highest returns, despite a small level of elite capture.[24] An ongoing DIME study in Mozambique studies targeting by leading commercial farmers in a community. These farmers receive input kits to sell on credit to other farmers, and they aggregate harvests for commercialization. These responsibilities may incentivize them to target smallholder farmers who are most likely to pay back the cost of inputs and sell back harvests. Preliminary results show that the profile of farmers targeted by commercial farmers and government extension workers is similar.

18 Jacob Moscona and Karthik A. Sastry, 2022, "Inappropriate Technology: Evidence from Global Agriculture," Unpublished manuscript, Social Science Research Network, last modified November 15, 2022.

19 Esther Duflo, Michael Kremer, and Jonathan Robinson, 2008, "How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya," *American Economic Review* 98 (2): 482–88.

20 Aurélie P. Harou, Malgosia Madajewicz, Hope Michelson, et al., 2022, "The Joint Effects of Information and Financing Constraints on Technology Adoption: Evidence from a Field Experiment in Rural Tanzania," *Journal of Development Economics* 155:102707.

21 Ricker-Gilbert, Jayne, and Chirwa (2011) show that a 1 kg fertilizer subsidy crowds out 0.22 kg of non-subsidized fertilizer in Malawi, and the size of the crowding-out effect depends on the profiles of farmers. See Jacob Rickert-Gilbert, Thomas S. Jayne, and Ephraim Chirwa, 2011, "Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi," *American Journal of Agricultural Economics* 93 (1): 26–42. On the other hand, Carter, Laajaj, and Yang (2021) show that there is little to no crowding-out effect of input subsidies on fertilizer use in Mozambique, a context where baseline fertilizer adoption is low. See Michael Carter, Rachid Laajaj, and Dean Yang, 2021, "Subsidies and the African Green Revolution: Direct Effects and Social Network Spillovers of Randomized Input Subsidies in Mozambique," *American Economic Journal: Applied Economics* 13 (2): 206–29.

22 Lori Beaman, Dean Karlan, Bram Thuysbaert, and Christopher Udry, 2013, "Profitability of Fertilizer: Experimental Evidence from Female Rice Farmers in Mali," *American Economic Review* 103 (3): 381–86.

23 Tavneet Suri, 2011, "Selection and Comparative Advantage in Technology Adoption," *Econometrica: Journal of the Econometric Society* 79 (1): 159–209.

24 Xavier Giné, Shreena Patel, Bernardo Ribeiro, and Ildrim Valley, 2022, "Efficiency and Equity of Input Subsidies: Experimental Evidence from Tanzania," *American Journal of Agricultural Economics* 104 (5): 1625–55; Maria Pia Basurto, Pascaline Dupas, and Jonathan Robinson, 2020, "Decentralization and Efficiency of Subsidy Targeting: Evidence from Chiefs in Rural Malawi," *Journal of Public Economics* 185:104017.

How and when should the subsidy be delivered?

The delivery mechanism for subsidized agricultural inputs often depends on the presence of private agro-dealers. With a robust network of agro-dealers, distributing inputs through this channel can strengthen agro-dealer businesses, improve input access, and create a sustainable distribution system.[25] In areas where the supply of inputs in local markets is limited, offering vouchers to redeem at private sellers may impose additional transportation costs on remote farmers and further increase input prices. In-kind delivery may be more effective, at least in the short term, in these contexts. On the other hand, in places where inputs are widely available for purchase locally, delivering subsidized inputs in kind can lower the market demand and the price of inputs sold by private sellers. This may have the unintended consequence of reducing the availability of the inputs once the subsidy is withdrawn, especially when there is a crowding-out effect from the subsidy. Offering vouchers that can be redeemed at a private seller may be more appropriate in these contexts. More research is needed to understand how to incentivize and thicken market participation by private agro-dealers, who will be responsible for input delivery and distribution in the long term.

Subsidies should be delivered before the subsidized inputs are needed because delays may cause farmers to wait for the subsidized inputs to arrive and thus apply them too late.[26] Moreover, if the co-payments required for input subsidies are high, offering input vouchers well before planting may increase adoption, as farmers will still have cash on hand from the previous harvest sales.[27]

Is the subsidy alone enough?

Financial constraints are not the only reason for low adoption of input technologies. Complementary interventions addressing knowledge, market access (input and output), insurance, and savings may also be necessary to ensure that subsidies drive increased adoption of input technologies. For example, DIME is conducting two studies in Mozambique to unpack the roles of financial, knowledge, and market-access constraints. With FAO, DIME designed a large-scale experiment in which farmers receive either agricultural training or input vouchers alone, or both together. By comparing these groups, we can estimate the relative effect of each constraint and the combined effect of both training and voucher programs. In another study, DIME examines the government's flagship agricultural development policy, which aims to empower the most productive farmers to become agricultural entrepreneurs. These farmers address coordination and market-access constraints in their local communities by facilitating input distribution and output aggregation. They also sell inputs on credit and offer technical assistance, reducing financial and knowledge constraints. The impact evaluation aims to isolate these constraints by randomizing which services communities receive.

25 Jesse M. Cunha, Giacomo De Giorgi, and Seema Jayachandran, 2018, "The Price Effects of Cash versus In-Kind Transfers," *The Review of Economic Studies* 86 (1): 240–81.

26 Jérémie Gignoux, Karen Macours, Daniel Stein, and Kelsey Wright, 2022, "Input Subsidies, Credit Constraints, and Expectations of Future Transfers: Evidence from Haiti," *American Journal of Agricultural Economics* 105 (3): 809–35.

27 Esther Duflo, Michael Kremer, and Jonathan Robinson, 2011, "Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya," *American Economic Review* 101 (6): 2350–90.

Other policies that may complement an input subsidy program include the following:

- Crop insurance to reduce the risk of investments[28]
- Savings accounts to smooth consumption and spur investment[29]
- Improvements to fertilizer and seed quality and input certification if farmers mistrust the quality of inputs[30]
- Price premiums to address a lack of market demand for high-quality outputs

Will the subsidy's impact last?

If farmers' demand is not sensitive to small price differences, a lower subsidy rate may allow governments to save money without decreasing input adoption. For example, a DIME field experiment in Ghana on payments for ecosystem services to plant trees found that the initial payment (around US$100) generated high take-up, with over 90 percent of farmers agreeing to plant trees. Reducing payments by half would lead fewer than 20 percent of farmers to change their decision, meaning the project could double its tree coverage with much lower payments.[31]

There is little evidence on whether a one-time subsidy is sufficient to support the sustained use of inputs or the conditions needed for sustainability. A few studies have found modest persistence and learning spillovers to beneficiaries' social networks, but the effects fade over time.[32] If farmers have limited experience with new technology, a one-time subsidy may be enough to demonstrate the value of new inputs and sustain their use. If a one-time subsidy increases agricultural income in the first year, it can also support investment in the following year. However, gains from input adoption depend heavily on weather, geography, and environmental factors, which make it difficult for farmers to learn the true impact of new input technologies. In these cases, subsidies should be maintained over multiple seasons to allow farmers to learn about the technology under various conditions. This is especially critical for inputs that aim to build farmers' resilience to shocks.

28 Dean Karlan, Robert Osei, Isaac Osei-Akoto, and Christopher Udry, 2014, "Agricultural Decisions after Relaxing Credit and Risk Constraints," *The Quarterly Journal of Economics* 129 (2): 597–652.

29 Michael R. Carter, Rachid Laajaj, and Dean Yang, 2017, "Subsidies, Savings, and Information Spillovers: A Randomized Experiment in Mozambique," World Bank Correspondence.

30 essa Bold, Selene Ghisolfi, Frances Nsonzi, and Jakob Svensson, 2022, "Market Access and Quality Upgrading: Evidence from Four Field Experiments," *American Economic Review* 112 (8): 2518–52; Maha Ashour, Daniel Orth Gilligan, Jessica Blumer Hoel, and Naureen Iqbal Karachiwalla, 2018, "Do Beliefs about Herbicide Quality Correspond with Actual Quality in Local Markets? Evidence from Uganda," *The Journal of Development Studies* 55 (6): 1285–1306.

31 Daan van Soest, Ty Turley, Paul Christian, Eline van der Heijden, and Rahel Kitessa, 2018, "Can Uniform Price Auctions Inform the Design of Payments for Ecosystem Services Schemes? Evidence from the Lab and Field," Unpublished manuscript, last updated March 18, 2018.

32 Carter, Laajaj, and Yang, 2021.

Complementary Interventions to Maximize the Productive Impacts of Irrigation and Transform Food Systems

Climate change is a growing threat to global food and nutrition security. Climate change imperils food availability and accessibility as well as the livelihoods of almost half the world's population.[33] To meet this challenge, we must enhance food systems' resilience to climate change and increase their productivity by investing strategically in climate-resilient technology and infrastructure.

Irrigation infrastructure is a potentially transformative investment in productive, climate-resilient food systems. Irrigation can increase agricultural productivity per hectare by as much as 100 percent across a range of contexts, primarily by adding agricultural seasons and reducing dependence on rainfall.[34] When farmers can grow a wider variety of crops in more seasons, the food system is more productive and more resilient to climate shocks, and households have a higher and more consistent annual income.

Yet irrigation has enormous untapped potential. Irrigation infrastructure is expensive to build, so a high level of utilization is necessary for investments to be sustainable.[35] Despite large benefits, irrigation is often underutilized.[36] As a result, substantial fractions of "command areas" (land that is irrigable under an irrigation scheme) remain under rainfed agriculture. When farmers do not extract enough benefit from irrigation to offset ongoing costs, they do not use it, making the infrastructure less effective and less likely to be well maintained.

How can we increase farmers' utilization of irrigation to make sure investments deliver?

Complementary interventions are essential to address farmers' constraints to adopting irrigated agriculture and maximize irrigation's impact. To unlock the potential of irrigation infrastructure, we need to consider how and why farmers (do not) use it and develop complementary interventions with their needs in mind.

This chapter presents six evidence-based interventions to increase the utilization of irrigation, targeting obstacles related to labor, land, output markets, credit, information availability, and operations and maintenance. Constraints will be context specific, so it is likely that a combination of complementary activities will be needed to maximize the impact of irrigation for agricultural productivity and climate resilience. Subsequent phases of programming, if carefully coordinated, can support the long-term utilization of irrigation infrastructure and maximize the returns to the overall investment.

33 Benjamin Davis, Erdgin Mane, Leman Yonca Gurbuzer, et al., 2023, "Estimating Global and Country-Level Employment in Agrifood Systems," *FAO Statistics Working Paper* Series 23/34, Food and Agriculture Organization of the United Nations, Rome.

34 Esther Duflo and Rohini Pande, 2007, "Dams," The Quarterly Journal of Economics 122 (2): 601–46; Maria Jones, Florence Kondylis, John Loeser, and Jeremy Magruder, 2022, "Factor Market Failures and the Adoption of Irrigation in Rwanda," *American Economic Review* 112 (7): 2316–52.

35 Vivien Foster, 2010, Africa's Infrastructure: A Time for Transformation, *Africa Development Forum* (Washington, DC: World Bank).

36 Elinor Ostrom and Roy Gardner, 1993, "Coping with Asymmetries in the Commons: Self-Governing Irrigation Systems Can Work," *Journal of Economic Perspectives* 7 (4): 93–112; Andrew Dillon and Ram Fishman, 2019, "Dams: Effects of Hydrological Infrastructure on Development," *Annual Review of Resource Economics* 11:125–48.

Opportunities for Impact

To increase the utilization of irrigation infrastructure, consider the following six complementary interventions:

- Reduce labor requirements to make irrigation easier for farmers to use.
- Facilitate land exchanges.
- Connect farmers to buyers to secure better prices.
- Unlock finance to alleviate credit constraints.
- Provide information on complementary technologies and practices through agricultural extension.
- Promote water-use efficiency to ease cooperative operations and maintenance.

The complementary interventions discussed in this chapter were tested in the context of hillside irrigation schemes in Rwanda, and examples from this context are provided throughout. An ongoing partnership between Rwanda's Ministry of Agriculture (MINAGRI), DIME, and the World Bank's Agriculture and Food Global Practice has supported a series of joint impact evaluations of complementary interventions that aim to increase the use of World Bank–financed hillside irrigation schemes in Rwanda. Ongoing impact evaluations are integrated with the government of Rwanda's national agricultural sector strategy, optimizing the already high returns to investments in hillside irrigation schemes and generating insights for irrigation investments in other countries.[37]

Reduce labor requirements to make irrigation easier for farmers to use.

Obstacle

Irrigation is often associated with the cultivation of high-value crops, which may involve labor-intensive watering and cultivation practices. In Rwanda, labor intensity has been found to limit the use of irrigation infrastructure. If households rely predominantly on their own agricultural labor, this level of labor intensity limits their ability to cultivate irrigated high-value crops.[38]

Opportunities

Small-scale irrigation technologies that reduce the labor requirements associated with irrigation may help more farmers use irrigation infrastructure. DIME's ongoing partnership in Rwanda is testing the impact of small-scale technologies such as rain hoses and drip irrigation on the adoption of irrigation in the context of the Sustainable Agriculture Intensification and Food Security Project (SAIP). These technologies could enable farmers to irrigate their crops in significantly less time, reducing the need for hired labor and making irrigation more accessible to all farmer households.

37 Foster, 2010.
38 Jones et al., 2022.

Facilitate land exchanges.

Obstacle

Irrigation schemes cover the landholdings of a broad range of households. Some households may benefit more from irrigated agriculture, and others may find themselves with more irrigable land than they can irrigate themselves.[39]

Opportunities

Facilitating land exchanges between farmers can increase the use of irrigation schemes. When land is readily traded across farmers, the use of irrigation schemes increases because farmers who do not benefit from irrigation exit the scheme while farmers who could benefit enter it, as found in a study DIME conducted jointly within the African Development Bank–financed Sustainable Land Water Resource Management Project in Mozambique. Evidence from Kenya shows subsidizing land rentals can enable youth to expand into commercial agriculture.[40] In Rwanda, land markets have enabled farmers who are not using irrigation to rent their land to farmers who are interested in irrigation; however, many potential land rentals do not occur. An ongoing impact evaluation with the Ministry of Agriculture is testing the impact of strategies to enable land rentals—including improved rental contracts and empowering intermediary farmer brokers—on irrigation use. (Despite these strategies, emerging evidence suggests that most rental arrangements remain driven by social ties.)

Connect farmers to buyers to secure better prices.

Obstacle

Farmers often use irrigation infrastructure to transition to high-value crops.[41] Limited access to well-functioning output markets, however, prevents farmers from participating in value chains for irrigated produce.[42] This means they don't see the full value of their crops—or of irrigation.

Opportunities

Linking farmers to buyers may help them receive better output prices, encouraging the use of irrigation. In Rwanda, farmers receive much lower prices for their produce than those offered by buyers in nearby commercial centers. Ongoing impact evaluations with the SAIP and local NGO partners are testing the impact of strategies that link farmers to buyers—through interactive voice response over mobile phones and farming-as-a-business trainings, or through a full off-taker model which we describe in the next sub-section—on the output prices farmers receive and, in turn, their adoption of irrigation.

39 Jones et al., 2022.
40 Michelle Acampora, Lorenzo Casaburi, and Jack Willis, 2022, "Land Rental Markets: Experimental Evidence from Kenya," *NBER Working Paper 30495*, National Bureau of Economic Research, Cambridge, MA.
41 Foster, 2010; Jones et al., 2022.
42 Nava Ashraf, Xavier Giné, and Dean Karlan, 2009, "Finding Missing Markets (and a Disturbing Epilogue): Evidence from an Export Crop Adoption and Marketing Intervention in Kenya," *American Journal of Agricultural Economics* 91 (4): 973–90.

Unlock finance to alleviate credit constraints.

Obstacle

Irrigation allows farmers to transition to high-value crops, but this often requires expensive inputs: seeds, fertilizer, and pesticides. Limited access to credit prevents farmers from affording these profitable technologies.[43] In different contexts, this barrier may be severe, depending on the specific crops and agricultural practices. In Rwanda, high-value horticulture for local markets does not require large expenditures on seed and fertilizer compared with other crops, so barriers to accessing credit markets do not limit use of hillside irrigation schemes.[44]

Opportunities

There are multiple strategies to enable farmers with limited credit access to purchase inputs. Commitment savings accounts allow farmers to save at harvest time for future input purchases. In Rwanda, this approach was embedded into savings and credit cooperatives and was effective at increasing fertilizer use. Under a different model, farmers make multiple small payments after harvest to accumulate sufficient savings for future input purchases. This model has been implemented successfully by One Acre Fund.[45] Integrating farmers into well-functioning value chains can also overcome credit constraints. In these cases, buyers make agreements with farmers who are reliable suppliers and offer them credit to make investments. For example, sugar cane buyers have enabled insurance investments in Kenya, coffee buyers have enabled agricultural extension in Rwanda, and cocoa buyers have enabled input investments in Sierra Leone.[46]

Provide information on complementary technologies and practices through agricultural extension.

Obstacle

Irrigation often enables new crops and farming practices. If farmers have limited information about these crops and practices, they may not use irrigation schemes. For instance, early large-scale irrigation schemes in India were underutilized until the introduction of irrigated sugarcane as a high-value crop.[47] In Rwanda, by contrast, high-value horticulture for local markets was already familiar to farmers, so limited information about complementary crops did not affect the use of hillside irrigation schemes.[48]

Opportunities

Demonstration plots are effective at increasing farmers' understanding of complementary agricultural technologies and practices, encouraging irrigation use. Decentralized demonstration can magnify these impacts by enabling farmers to learn for themselves and from others about new agricultural technologies.[49]

Temporarily subsidizing complementary technologies can also spur adoption. A large-scale study in Mozambique finds that farmers who learn about fertilizer from other farmers who received temporary subsidies persistently increase their own fertilizer use.[50]

Promote water-use efficiency to ease cooperative operations and maintenance.

Obstacle

Irrigation schemes are engineered to deliver a fixed quantity of water each season. When farmers overuse water, a "tragedy of the commons" may unfold if there is not enough water left to achieve full use of the irrigation infrastructure.[51] This makes the scheme unsustainable in the long run.

Opportunities

Promoting water-use efficiency is key to ensuring the long-term sustainability of irrigation schemes. In India, drip irrigation (a water-efficient irrigation technology) improved water-use efficiency and, in turn, increased irrigated area.[52] In Mozambique, water intake into medium irrigation schemes was limited by pumping capacity, leading farmers to lack sufficient water to meet their requirements. Detailed survey and water use measurements showed that this water scarcity was driven by a misallocation problem: farmers lacked information about how the amount of water their crops require changes over the course of the cropping cycle, and they overused water unnecessarily as a result. Providing information about water requirements, combined with encouragement not to overuse water, has the potential to reduce water scarcity.[53] In other contexts, farmers have formed cooperatives to coordinate water use and maintenance, avoiding overuse and achieving sustainability.[54] Alternatively, in Rwanda, centrally managed operations and maintenance were well implemented, ensuring scheduled use and well-functioning infrastructure.[55]

43 Dean Karlan, Robert Osei, Isaac Osei-Akoto, and Christopher Udry, 2014, "Agricultural Decisions after Relaxing Credit and Risk Constraints," *The Quarterly Journal of Economics* 129 (2): 597–652.

44 Jones et al., 2022.

45 Joshua Deutchmann, Maya Duru, Kim Siegal, and Emilia Tjernstrom, 2023, "Relaxing Multiple Agricultural Productivity Constraints at Scale," Unpublished manuscript, Last modified May 15, 2023.

46 Lorenzo Casaburi and Jack Willis, 2018, "Time versus State in Insurance: Experimental Evidence from Contract Farming in Kenya," *American Economic Review* 108 (12): 3778–813; Rocco Macchiavello and Ameet Morjaria, 2021, "Competition and Relational Contracts in the Rwanda Coffee Chain," *The Quarterly Journal of Economics* 136 (2): 1089–1143; Lorenzo Casaburi and Tristan Reed, 2022, "Using Individual-Level Randomized Treatment to Learn about Market Structure," *American Economic Journal: Applied Economics* 14 (4): 58–90.

47 Donald W. Attwood, 2005, "Big Is Ugly? How Large-Scale Institutions Prevent Famines in Western India," *World Development* 33 (12): 2067–83.

48 Jones et al., 2022.

49 Florence Kondylis, John Loeser, Mushfiq Mobarak, Maria Jones, and Daniel Stein, 2023, "Learning from Self and Learning from Others: Experimental Evidence from Bangladesh," *Policy Research Working Paper* WPS 10545, World Bank, Washington, DC.

50 Michael Carter, Rachid Laajaj, and Dean Yang, 2021, "Subsidies and the African Green Revolution: Direct Effects and Social Network Spillovers of Randomized Input Subsidies in Mozambique," *American Economic Journal: Applied Economics* 13 (2): 206–29.

51 Elinor Ostrom, 1990, Governing the Commons: The Evolution of Institutions for Collective Action (Cambridge, UK: Cambridge University Press).

52 Ram Fishman, Xavier Giné, and Hanan G. Jacoby, 2023, "Efficient Irrigation and Water Conservation: Evidence from South India," *Journal of Development Economics* 162:103051.

53 Paul Christian, Florence Kondylis, Valerie Mueller, Astrid Zwager, and Tobias Siegfried, 2022, "Monitoring Water for Conservation: A Proof of Concept from Mozambique," *American Journal of Agricultural Economics* 104 (1): 92–110.

54 Edella Schlager and Elinor Ostrom, 1992, "Property-Rights Regimes and Natural Resources: A Conceptual Analysis," *Land Economics* 68 (3): 249–62.

55 Jones et al., 2022; Ostrom, 1990.

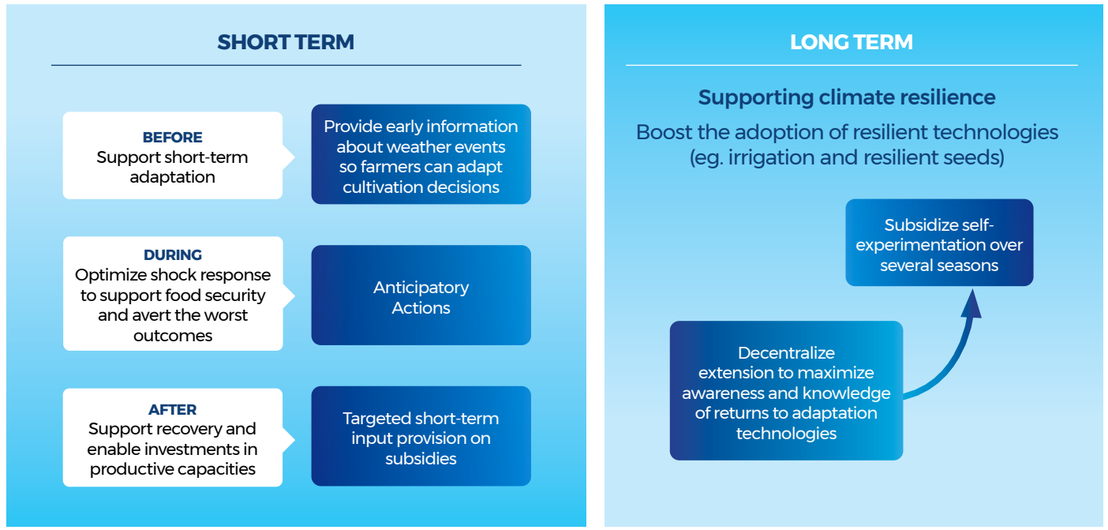
4 Supporting Climate Resilience for Vulnerable Farmers

Floods, droughts, and cyclones devastate the livelihoods of the poorest with increasing frequency. These direct consequences of climate change therefore increasingly challenge the global poverty alleviation agenda. These disasters are concentrated where the world's poorest live and have more severe consequences on high-poverty areas, where agriculture, which is directly impacted by climate risk, is the main livelihood.[56] New implementation modalities are needed to maximize the impact of scarce resources to alleviate poverty in rural areas.[57]

How can we help farmers cope with and recover from climate disasters and make them less vulnerable to climate risks?

This chapter considers evidence for short- and long-term actions the development community can take to build climate resilience in the face of growing weather uncertainty and increasingly frequent environmental crises. In the short term, urgent humanitarian relief actions may be needed to help vulnerable populations anticipate and recover from disasters like droughts, floods, and hurricanes. In the long term, we can help households reduce their climate vulnerability with new climate-resilient technologies and better forecasts of climate and weather events (See Figure 4).

FIGURE 4 – **Building farmer resilience in the short and long term**



56 IPCC, 2023, Climate Change 2022: Impacts, Adaptation and Vulnerability, Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, UK: Cambridge University Press).

57 World Bank, 2018, Poverty and Shared Prosperity 2018: Piecing Together the Poverty Puzzle (Washington, DC: World Bank).

Opportunities for Impact

Through anticipatory action, short term relief can be optimized using forecasts to accelerate humanitarian responses immediately as a shock is predicted, instead of traditional post-disaster relief. Anticipatory action means using disaster forecasts to commit to and plan for humanitarian relief activities such as cash transfers or food distribution. Traditionally, governments or relief organizations have waited for a negative shock (such as an extreme weather event) to strike and then mobilized a response to support relief and recovery. By instead agreeing in advance on actions that will be taken for a given population when a pre-specified risk forecast is triggered, governments and organizations can deliver assistance quickly after a crisis warning is issued, minimizing the time between the shock and humanitarian relief—and in some cases reaching households even before a shock occurs.

In the long term, we can use the improved forecast data and promotion of climate-resilient technologies to help farmers mitigate their exposure and reduce impacts of shock. Forecasts can help farmers make better farming decisions under weather uncertainty, and insurance and credit guarantees can be optimized to help farmers. Technologies like improved seeds and irrigation can reduce vulnerability to weather variability. Understanding how these interventions interact is also crucial.

Can anticipatory action improve traditional humanitarian relief?

Emerging evidence suggests anticipatory action can help households cope with the immediate consequences of climate change: we do not need to wait for new technologies or forecasting improvements to avoid and mitigate harm. In an impact evaluation implemented with the World Food Programme in Nepal and Balngladesh, DIME compared the impact of a cash transfer made as quickly as possible, on the basis of forecasts indicating the high likelihood of a shock, with the impact of a cash transfer made after the shock had occurred (the traditional response timeline). From a budgetary perspective these interventions are equal, so the comparison highlights the gains from acting as quickly as possible.

Anticipatory action helped households mitigate the worst immediate consequences of the flood shock in Nepal. Households that received the cash transfer early were more likely to be food secure and less likely to report anxiety and depression at a time when they would otherwise have been waiting for relief. The impact of the early cash transfers also did not dissipate immediately. Once both groups of households had received cash transfers, their food security and mental health were equivalent.

However, more support may be needed to help families recover after a shock: on average, the anticipatory-action group did not have better outcomes on livelihood investments or income in the following season. This suggests that the main benefit of early financial assistance is to support immediate humanitarian relief, which is in line with a similar evaluation of drought response in Niger.[58]

While evidence on the benefits of anticipatory action is increasing, there are potential drawbacks that warrant further investigation. While evidence from floods in Bangladesh and severe winter storms in Mongolia suggests that cash transfers help boost livelihood capacities, more evidence is needed on the specific advantages of anticipatory action.[59] Furthermore, if forecasts are incorrect, resources may be targeted less effectively than they would have been after the shock. This risk must be minimized. More evidence is needed to evaluate how the benefits of anticipatory action weigh against the possibility of targeting errors due to inaccurate forecasts, as well as how to overcome anticipatory action's potential limitations by combining it with other forms of assistance.

58 Patrick Premand and Quentin Stoeffler, 2022, "Cash Transfers, Climatic Shocks and Resilience in the Sahel," *Journal of Environmental Economics and Management* 116:102744.

59 Ashley Pople, Ruth Hill, Stefan Dercon, and Ben Brunckhorst, 2021, "Anticipatory Cash Transfers in Climate Disaster Response," *CSAE Working Paper* WPS/2021-07, Center for the Study of African Economies, Oxford, UK; Clemens Gros, Evan Easton-Calabria, Meghan Bailey, et al., 2020, "The Effectiveness of Forecast-Based Humanitarian Assistance in Anticipation of Extreme Winters: A Case Study of Vulnerable Herders in Mongolia," *Disasters* 46 (1): 95–118.

How can we further help farmers reduce their climate vulnerability?

Using improved forecasts to make better decisions

Climate scientists have improved at predicting the weather because of increased data availability, more sophisticated measurement tools, and improvements in computing power. These improvements enable better forecasts of weather parameters that affect agricultural livelihoods, like the onset of the monsoon. In India, for example, novel forecasts of the starting date of the Indian monsoon from the Potsdam Institute for Climate Research have been accurate to within one week in each of the past 10 years.[60]

Providing access to accurate forecasts can help farmers make better-informed decisions about the upcoming agricultural season—such as decisions about how much land they cultivate, which crops they grow, and how much fertilizer they apply. For example, in India, DIME has found that farmers who received a forecast indicating a longer-than-expected growing season increased the land they cultivated by 15 percent and spent over a third more on up-front investments.[61] Future evaluations should address how these impacts materialize at scale—for example, when delivered broadly enough to affect prices.

Improved forecasts also enable us to offer credit or insurance guarantees that are linked to specific weather risks to help farmers adapt to these risks. For instance, improved forecasts strengthen our understanding of the underlying risk of crop insurance or guaranteed credit systems. An evaluation of a credit guarantee for farmers vulnerable to flooding in Bangladesh demonstrated the potential gains from improved financial instruments. Households that were informed they could access extra loan liquidity before or during a flood shock were able to insulate themselves and make more productive investments before the flood—such as increasing the area of their agricultural land. Flood-affected households that were offered emergency credit also experienced fewer coping strategies after the flood, achieving higher consumption than other flood-affected households.[62]

Supporting the adoption of climate resilient technologies

In the long term, we can help people not only recover from climate shocks but also avoid or mitigate them in the first place. Technological interventions that reduce households' climate risk include large-scale infrastructure (irrigation), improved inputs (seeds and fertilizer), and training about climate-smart practices. Emerging evidence suggests that adopting climate-resilient technology can help insulate households from the consequences of climate change. Because the advantages of climate-resilient technologies are dynamic and context specific, special considerations are warranted when promoting them. More evidence is needed to ensure sustainable, continued adoption of these technologies in varied contexts and to understand their limitations.

60 Fiona Burlig, Amir Jina, Erin M. Kelley, Gregory V. Lane, and Harshil Sahai, 2024, "Long-Range Forecasts as Climate Adaptation: Experimental Evidence from Developing-Country Agriculture," *NBER Working Paper* 32173, National Bureau of Economic Research, Cambridge, MA.

61 Burlig et al., 2024.

62 Gregory Lane, 2024, "Adapting to Climate Risk with Guaranteed Credit: Evidence from Bangladesh," *Econometrica* 92 (2): 355–86.

Climate-resilient technology can reduce climate risks. Recent work in multiple settings demonstrates that climate-resilient technologies generate positive returns in expected contexts, such as when a flood or drought occurs. For instance, in Bangladesh, a DIME impact evaluation showed that improved seeds helped protect yields from soil salinity caused by floods.[63] Farmers who used the improved seeds and experienced floods saw higher yields than farmers who experienced floods but did not use the improved seeds. In Mozambique and Tanzania, distribution of drought-tolerant maize seeds and complementary training helped farmers avoid yield losses during droughts.[64]

Sustainable adoption of climate-resilient technology requires a resilience lens that recognizes that people need to experience new technologies firsthand and under the circumstances when these technologies are expected to have real benefits. Adoption of climate-resilient technology can be accelerated through carefully designed extension systems and short-term subsidies to promote self-experimentation. More evidence on the design of impactful input subsidy and extension systems can be found in chapters 1 and 2.

Perceived gains from adopting climate-resilient technologies can depend on weather and actual experiences with shocks. Subsidized self-experimentation should be sustained over multiple seasons to allow farmers to learn about a technology under varying conditions. For instance, in Bangladesh, farmers who experienced floods during the demonstration year were more likely to adopt climate-resilient technologies in the following season, highlighting the fact that climatic variation drives the speed of learning about these technologies.[65] Similarly, in Mozambique and Tanzania, farmers who did not experience a drought (and thus did not observe gains from drought-tolerant seeds) were less likely to purchase them in subsequent seasons.[66] Further research is needed to understand how to address this problem—for example, by emphasizing in trainings when farmers can expect to see benefits, or through repeated promotion, where farmers experience new subsidies or trainings until they see benefits for themselves.

Understanding synergies between interventions

DIME is launching impact evaluations to understand how different climate resilience programs interact. Is it beneficial to provide households with multiple climate resilience programs—for instance, by combining anticipatory action with climate-resistant technology? Or does investing in one program lead households to invest less in another? For example, receiving financial assistance through anticipatory action may encourage farmers to invest in climate-resilient technologies by lowering the risk associated with crop failure. However, it could also lead farmers to continue to plant only traditional varieties rather than experimenting with drought-resistant ones because they know insurance will pay out in the event of poor rainfall. In Mozambique and Tanzania, an impact evaluation tested offering farmers improved seeds and rainfall insurance together, finding that both help buffer agricultural yields from rainfall failures. Farmers who used the improved seeds and benefited from insurance payouts had higher agricultural investments in subsequent seasons, suggesting that insurance crowded in spending and investment rather than crowding them out.[67]

63 Florence Kondylis, John Ashton Loeser, Mushfiq Mobarak, Maria Ruth Jones, and Daniel Stein, 2023, "Learning from Self and Learning from Others: Experimental Evidence from Bangladesh," *Policy Research Working Paper* WPS 10545, World Bank, Washington, DC.

64 Stephen R. Boucher, Michael R. Carter, Jon Einar Flatnes, et al., 2021, "Bundling Stress Tolerant Seeds and Insurance for More Resilient and Productive Small-Scale Agriculture," *NBER Working Paper* 29234, National Bureau of Economic Research, Cambridge, MA.

65 Kondylis et al., 2023.

66 Boucher et al., 2021.

67 Burlig et al., 2024.

Anticipatory action and climate-resilient technology may also have consequences for those who don't receive these programs. For instance, providing forecasts to a select number of farmers can help the rest of the community adjust their decision-making as well. Similarly, recipients of climate-resilient technologies may share with others and be better able to support their peers if their own flood damages are reduced. Considering how quickly new technologies spread is important to understand when and how to promote climate resilience for farmers.

Diversifying livelihoods

Finally, agriculture will always be affected by climate risk, and reducing risk may involve helping populations currently reliant on agriculture diversify their income sources or move out of agriculture altogether. This reality opens the space of overlapping interventions even further. For example, in Nicaragua, a DIME impact evaluation tested strategies for promoting livelihood diversification within a program implemented by Ministry of the Family that targeted households exposed to increasingly severe drought risk. This evaluation found that adding a capital grant or vocational training programs to a cash transfer improved income and consumption smoothing over droughts, and the productive asset grant achieved the biggest impacts on consumption.[68]

Considerations for Measurement

Understanding climate resilience implies unique considerations that don't always arise when studying interventions that are expected to have homogeneous impacts for all recipients in all periods of time.

Defining the precise times to measure outcomes is critical. Capturing dynamics and shocks means measuring outcomes at multiple points in time because impacts depend not just on average treatment effects but on treatment effects at multiple points in time—for example, as households experience and recover from shocks.

Measuring the ability of programs to foster resilience under different circumstances also requires a common measurement framework to ensure potential differences in impacts are due to varying conditions, not differences in the ways key outcomes are measured. It is useful to choose different contexts to study programs and apply similar surveys to programs across different contexts. Pre-positioning impact evaluations in areas where we expect climate events or climate uncertainty, for example, allows us to understand whether the impact of these programs differs under different climatic conditions. Designing surveys with similar outcomes makes it possible to understand how similar programs operate in different conditions.

Sometimes, implementing climate resilience activities will require acting quickly, without time to collect baseline surveys or conduct for-purpose targeting registration exercises. Given these needs, it is helpful to plan registration data in ways that allow organizations to quickly select participants for impact evaluations, target recipients for resilience support, and identify the highest priority indicators we would normally want in a baseline.

68 Karen Macours, Patrick Premand, and Renos Vakis, 2022, "Transfers, Diversification and Household Risk Strategies: Can Productive Safety Nets Help Households Manage Climatic Variability?," *The Economic Journal* 132 (647): 2438–70.

Developing Markets and Value Chains

Farmers must be able to access good prices and markets for high-value products to realize strong profits from their outputs. This fact has not always been recognized by agricultural development initiatives, which for decades have focused on improving on-farm production and access to inputs. However, simply increasing production is not enough to increase poor, rural farmers' income and reduce poverty. Farmers' profits also depend on their ability to access markets and get good prices for their products. Likewise, access to new markets can impact farmers' production and input choices.

How can we improve farmers' market access and ensure they get the best possible output prices?

This chapter considers interventions aimed at improving farmers' ability to get the best possible prices for their goods and their access to markets for high-value products. It also considers the implications of these interventions for their input and production choices.

First things first: The importance of value chain structure and diversity

Market and price interventions need to consider the unique features of farmers' specific crops and value chains. Farmers rarely sell directly to final consumers. Instead, they typically sell to traders or transporters, either at their farm gate or in nearby regional markets. Those products may then be sold to processors or held at storage facilities, then passed on to wholesalers for domestic distribution or exporters for international shipment. The unique structure of any given value chain can greatly influence the prices and markets available to farmers producing within it.

The great diversity of value chains can make it difficult to draw global lessons from individual case studies. A full treatment of different value chain features and their implications for the needs of farmers and other actors falls outside the scope of this chapter.[69] Instead, we will emphasize the distinction between **staple crops**, which often serve domestic markets, and **cash crops**, which may serve international export markets. This distinction can greatly influence the formality of a value chain, the availability of finance, the market value of products, and the extent of market power at different points in the value chain. Some additional considerations when choosing a value chain are highlighted at the end of the chapter.

69 For recent papers discussing value chain structures and their implications for value chain actors, see Lenis Saweda O. Liverpool-Tasie, Ayala Wineman, Sarah Young, et al., 2020, "A Scoping Review of Market Links between Value Chain Actors and Small-Scale Producers in Developing Regions," *Nature Sustainability* 3 (10): 799–808; Christopher B. Barrett, Thomas Reardon, Johan Swinnen, and David Zilberman, 2022, "Agri-food Value Chain Revolutions in Low- and Middle-Income Countries," Journal of Economic Literature 60 (4): 1316–77; Kate Ambler, Alan de Brauw, Sylvan Herskowitz, and Cristhian Pulido, 2023, "Finance Needs of the Agricultural Midstream," *Food Policy* 121:102530.

Opportunities for Impact

Interventions to improve farmers' access to better prices and markets can take many forms:

- **Product certification and quality differentiation** incentivize farmers to raise the quality of their production in exchange for better prices.
- **Storage** investments, such as warehousing and hermetically sealable bags, can help farmers avoid selling at harvest, when prices are lowest.
- **Price advisories** and **digital marketplaces** focus on addressing information gaps and potential coordination inefficiencies.

Value chain interventions are diverse, and evidence is mixed. Table 2 summarizes the existing evidence for each of these interventions, distinguishing between staple and cash crops. The color of the cell indicates the depth of evidence in that space: darker shades of green indicate a bigger body of evidence, while gray indicates that there is no rigorous causal evidence. A plus sign indicates that these interventions have generally positive effects, based on existing evidence. "0" indicates that the literature finds limited effects or significant caveats.

TABLE 2 – Evidence for the Impact of Different Value Chain Interventions

	Value Chain / Market	
	Staple Crop / Domestic Market	Cash Crop / International Market
Quality Differentiation and Certification	**+/0** Farmers may benefit, but the viability of high-value staple markets is context dependent.	**+/0** There are possible benefits, but sustainability is challenging. Complementary constraints still need to be addressed.
Storage	**+/0** Storage may be helpful, but only if smallholders can be supported to overcome constraints: liquidity, transaction costs, storage technology, and risk-aversion.	**?** Evidence is lacking. Large buyers and exporters may have already solved this problem for themselves.
Price Advisories	**0** The evidence suggests minimal or trivial effects for stand-alone interventions.	**0** The evidence suggests minimal or trivial effects for stand-alone interventions.
Digital Marketplaces	**+/0** There are positive effects for large farmers, but smallholders are unable to use them.	**?** There is no existing evidence. Limited numbers of buyers may make these linkages clearer.

Can quality differentiation or certification increase farmers' access to better prices?

Farmers may struggle to get good prices for high-quality produce if markets do not differentiate levels of product quality and thus do not reward higher-quality products. In these cases, markets may unravel, with everyone producing low-quality products for low prices. This could leave potentially profitable investments neglected.

If product quality is difficult to observe, policies to improve buyers' quality differentiation are a necessary first step for creating markets for high-value products. A study of the onion value chain in Senegal shows that even low-tech investments in quality monitoring equipment can make buyers willing to pay a premium for quality and, in turn, can lead farmers to invest in the capital needed for high-quality production.[70] In Uganda, a similar study linked maize farmers to high-value markets and finds a positive response in their investments.[71] Two studies, in India and Vietnam, find that dairy farmers improve the quality of their production when quality measurement becomes possible and they are provided with access to high-value markets.[72]

Establishing systems of certification and traceability from producer to final seller can substantially raise the value of exported commodities. Certification can promote and reward higher-quality production, particularly for higher-value export commodities, such as coffee and tea, because international consumers are increasingly interested in knowing the source of their purchases. The evidence for certification, however, is mixed. One study finds that fair-trade certification can improve prices for farmers, particularly when world prices fall below the fair-trade prices.[73]

When they can access higher-value markets, farmers take advantage of these opportunities and adjust their input and production choices correspondingly. However, establishing these market linkages is challenging. Certification schemes are difficult to establish because systems of tracing and validation must run the full length of the value chain. This may only be viable for more formalized value chains, where links between actors are more stable across years and growing seasons. Even if these systems can be successfully established, and all other constraints to production and market access are resolved, unanticipated shifts in trade policy or a collapse in global prices could still cause the entire scheme to collapse, with considerable potential harm to farmers who invested in the new system.[74]

70 Tanguy Bernard, Alain de Janvry, Samba Mbaye, and Elisabeth Sadoulet, 2017, "Expected Product Market Reforms and Technology Adoption by Senegalese Onion Producers," *American Journal of Agricultural Economics* 99 (4): 1096–1115.

71 Tessa Bold, Selene Ghisolfi, Frances Nsonzi, and Jakob Svensson, 2022, "Market Access and Quality Upgrading: Evidence from Four Field Experiments," *American Economic Review* 112 (8): 2518–52.

72 Manaswini Rao and Ashish Shenoy, 2023, "Got (Clean) Milk? Organization, Incentives, and Management in Indian Dairy Cooperatives," Journal of Economic Behavior & Organization 212: 708–22; Christoph Saenger, Maximo Torero, and Matin Qaim, 2014, "Impact of Third-Party Contract Enforcement in Agricultural Markets: A Field Experiment in Vietnam," *American Journal of Agricultural Economics* 96 (4): 1220–38.

73 Raluca Dragusanu, Daniele Giovannucci, and Nathan Nunn, 2014, "The Economics of Fair Trade," *Journal of Economic Perspectives* 28 (3): 217–36.

74 Nava Ashraf, Xavier Giné, and Dean Karlan, 2009, "Finding Missing Markets (and a Disturbing Epilogue): Evidence from an Export Crop Adoption and Marketing Intervention in Kenya," *American Journal of Agricultural Economics* 91 (4): 973–90.

Can farmers delay sales to avoid low prices during harvest season?

Helping farmers sell at the right time can boost profits. When all farmers harvest seasonal crops within a narrow window of time, markets can be flooded, resulting in especially low seasonal prices. If this is the case, helping farmers sell a portion of their products further from the harvest season at higher seasonal prices is a promising way to increase profits.[75]

This is more easily said than done, however, because harvest follows a lean season in which most farmers exhaust their annual reserves. Even if farmers can store their produce without risk of spoilage, they may not be able to delay selling it if the lean season has fully depleted their reserves or pushed them into debt. Lean season loans may help farmers better smooth their consumption and avoid selling the entirety of their harvest when prices are lowest.[76] Additionally, interventions that provide better storage technology, such as hermetically sealed bags, can help farmers delay sales, obtain better prices, and improve their welfare.[77] Even low-cost interventions can generate meaningful welfare gains.

Delaying sales for future prices may expose farmers to new risks. The rationale for delaying sales to increase prices hinges on the assumption that prices vary substantially across the year. This may not be the case for all crops or seasons. One study of data from 30 countries across Africa finds that lean season prices do not always end up being higher than harvest season prices: in one out of six seasons, they were not.[78] This finding suggests that risk-averse farmers may have good reason for being resistant to storing their harvests when price uncertainty makes the returns to storage uncertain.

Can price advisories or digital marketplaces improve farmers' bargaining power?

Farmers need to find willing buyers offering acceptable prices for their products. This can be especially challenging if the costs to identify purchase offers are high. Further, smallholder farmers' ability to negotiate with traders may be limited if they don't know broader market prices.

Expanding mobile phone access has already spread information and improved prices for sellers.[79] This suggests that a lack of price information was hindering the efficiency of agricultural markets. In response, there has been enthusiasm for price advisories as a way to inform farmers of local prices and improve their bargaining power.

However, recent research on the impacts of stand-alone price advisories has failed to find strong effects, despite a relatively large body of evidence. Expanding mobile phone use may already have changed the information environment for regional price awareness, making a price advisory of only modest additional value. These results could also be due to trader collusion or a lack of the liquidity farmers need in order to access other buyers.[80]

Digital marketplaces offer a potential improvement over simple text-based price advisories. They can provide a menu of offers and link sellers directly to potential buyers. Platforms that include both sides of the market could also relieve information barriers and allow for more efficient product aggregation and coordination along the value chain.

Evidence on these emergent technologies is scarce, but one study in Uganda highlights reasons for optimism. In this study, researchers set up a digital marketplace for grain and promoted adoption and understanding among farmers. After mobilizing considerable adoption of the platform, they found that it caused a convergence of prices across disparate markets. However, benefits were concentrated among larger farmers and traders; smallholders were unable to use or benefit from the system. Once the subsidies linked to the study were removed, the marketplace was no longer viable and could not continue operating.[81] This study suggests that digital marketplaces do have the potential for system-wide benefits, but a sustainable model remains elusive. While technological literacy is improving, implementers should be conscientious about ensuring that marginalized smallholders are able to share in the benefits of these marketplaces as well.

What else should we consider when selecting a value chain and targeting an intervention?

The available markets and prices for smallholder farmers are greatly influenced by the unique features of the value chain they operate in, as discussed above. We have highlighted the distinction between cash and staple crops, but there are many other distinctions to consider when evaluating value chains and potential interventions. Here are a few further considerations:

- **Consider whether the proposed intervention addresses a first-order constraint as well as credit and input needs.** One likely reason price advisories have little effect is the fact that farmers face multiple constraints. Input and production barriers may impede the efficacy of market-focused interventions, since these interventions primarily occur after harvest. High transportation costs, limited access to inputs, and a lack of suitable knowledge about using a new technology can all limit the value of price information. Similarly, better storage options will not help if farmers face urgent liquidity needs at the time of harvest.
- **Account for the formality of the relationships between farmers and buyers/markets. If they are informal, consider whether agreements be enforced or sustained.** The formality of relationships between value chain actors can greatly impact the suitability of different value chain interventions. In particular, out-grower schemes aim to solve the need for price and market information by formalizing an agreement between producers and buyers. This type of relationship can help address smallholders' credit or extension needs. However, these relationships may not always be robust or enforceable. More often, transactions take place in informal markets, where reputation and trust play important roles in negotiating prices between buyers and sellers.

75 Marshall Burke, Lauren Falcao Bergquist, and Edward Miguel, 2019, "Sell Low and Buy High: Arbitrage and Local Price Effects in Kenyan Markets," *The Quarterly Journal of Economics* 34 (2): 785–842.

76 Burke, Bergquist, and Miguel, 2019.

77 Michael Brander, Thomas Bernauer, and Matthias Huss, 2021, "Improved On-Farm Storage Reduces Seasonal Food Insecurity of Smallholder Farmer Households: Evidence from a Randomized Control Trial in Tanzania," *Food Policy* 98:101891.

78 Lila Cardell and Hope Michelson, 2023, "Price Risk and Small Farmer Maize Storage in Sub-Saharan Africa: New Insights into a Long-Standing Puzzle," *American Journal of Agricultural Economics* 105 (3): 737–59.

79 Robert Jensen, 2007, "The Digital Provide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector," *The Quarterly Journal of Economics* 122 (3): 879–924; Jenny C. Aker, 2010, "Information from Markets Near and Far: Mobile Phones and Agricultural Markets in Niger," *American Economic Journal: Applied Economics* 2 (3): 4659.

80 Marcel Fafchamps, Ruth Hill, and Bart Minten, 2008, "Quality Control in Non-staple Food Markets: Evidence from India," *Agricultural Economics* 38 (3): 251–66; Sandip Mitra, Dilip Mookherjee, Maximo Torero, and Sujata Visaria, 2018, "Asymmetric Information and Middleman Margins: An Experiment with Indian Potato Farmers," *The Review of Economics and Statistics* 100 (1): 1–13.

81 Lauren Falcao Bergquist and Craig McIntosh, 2021, "Search Cost, Intermediation, and Trade: Experimental Evidence from Ugandan Agricultural Markets," *CEGA Working Paper* WPS-173, Center for Effective Global Action, University of California, Berkeley.

- **Look for where market power is concentrated along the value chain and consider how smallholders experience market power.** Market power plays a considerable role in the background of any and all price negotiations. Buyers operating in competitive markets cannot demand excessive mark-ups from smallholder sellers. However, if markets are fragmented, buyers may be able to take advantage of local monopsony power. Unless farmers can overcome search and transport costs to pursue outside options, they must accept these offers. On the other hand, sometimes market power has the unexpected benefit of aligning incentives along the value chain so that larger buyers are incentivized to help upstream producers resolve their credit or extension needs to secure their own supply. Disrupting these relationships could have the unintended effect of causing smallholders to lose their only sources for these informally provided services.[82]
- **Evaluate how risk is spread across the value chain and how smallholders experience it.** In the background of farmers' willingness to produce a new crop, take up storage, or commit to a different set of prices is their exposure to risk. Smallholders are typically very close to the poverty line and may be less willing to take on the risks associated with new activities. Even storage, which we consider to be almost a sure investment, may actually have intolerable risks, including the possibility of theft, spoilage, and especially price risk.

82 Lorenzo Casaburi and Tristan Reed, 2022, "Using Individual-Level Randomized Treatment to Learn about Market Structure," *American Economic Journal: Applied Economics* 14 (4): 58–90; Rocco Macchiavello and Ameet Morjaria, 2021, "Competition and Relational Contracts in the Rwanda Coffee Chain," *The Quarterly Journal of Economics* 136 (2): 1089–1143.

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