Questions

What have we learned from field experiments about:

- potential for yield gains in the immediate future and to 2050?
- how we can overcome hurdles?

How do they interact with climate change?
The Puzzle: Why has technology adoption lagged behind in SSA?

Fertilizer use per hectare of cropland, 1961 to 2020
Application of all fertilizer products (including nitrogenous, potash, and phosphate fertilizers), measured in kilograms of total nutrient per hectare of cropland.

Area planted with modern maize varieties, 1960-2000 (% total area harvested)

What have we learned from experiments?

Yield-increasing technologies may not be profit-maximizing

Agronomic trial with maize farmers in Kenya:
1) Large negative rate of return to the input package recommended by the gov't at the local input and output prices
2) Returns are sensitive to how farmers use the input

<table>
<thead>
<tr>
<th>Technology</th>
<th>Yield increase</th>
<th>Rate of return (one season)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 tsp of top dressing fertilizer &amp; HYV</td>
<td>Mean: +90%</td>
<td>Mean: -38.9%</td>
</tr>
<tr>
<td>(recommended by the gov't)</td>
<td>Median: +48.7%</td>
<td>Median: -49.4%</td>
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<tr>
<td>1/2 tsp of top dressing fertilizer</td>
<td>Mean: +47%</td>
<td>Mean: +36%</td>
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<tr>
<td></td>
<td>Median: +24.3%</td>
<td>Median: +23.9</td>
</tr>
<tr>
<td>1/4 tsp of top dressing fertilizer</td>
<td>Mean: +28.1%</td>
<td>Mean: +4%</td>
</tr>
<tr>
<td></td>
<td>Median: +8.9%</td>
<td>Median: -27.7%</td>
</tr>
</tbody>
</table>

“How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya” (Duflo et al., 2008)
What have we learned from experiments?
Farmer adoption can increase if technology is profitable, low-risk, and/or risk-reducing

Rainwater harvesting technology in Niger: (Aker and Jack, 2019)
Flood tolerant seeds for rice farmers in India: (Emerick et al, 2016)
Rice intensification system in Bangladesh (Barrette et al, 2021)
What have we learned from experiments?
But returns and constraints are extremely heterogeneous: no single binding constraint for the majority

- Innovations that address a specific constraint may be relevant only for a small group of farmers
- Profit gains for those farmers can be large, but the overall (or average) impact remains modest

### Types of farmer/market constraints

<table>
<thead>
<tr>
<th>Credit &amp; savings</th>
<th>Land</th>
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<tbody>
<tr>
<td>Risks</td>
<td>Markets</td>
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<tr>
<td>Information</td>
<td>Labor</td>
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What have we learned from experiments? Insights on deeper customization are still nascent but encouraging

More locally suitable technologies
Customized fertilizer advice: a 7-10% yield increase in Nigeria and Ethiopia but not in India

Real-time information
Accurate weather forecasts and pest alerts: a 7-10% increase in yield

Market linkages
A “yelp”-like service to rate artificial insemination (AI) service providers via mobile phones: A 27% increase in the success rate of AI

Innovations to address multiple constraints at once
One Acre Fund (high quality input on credit + extension): a 170% increase in the correct timing of fertilizer use; a 26% increase in yield

Customized fertilizer advice (Arouna et al, 2021; Ayelaw et al, 2022; Cole et al 2023)
Weather forecasts and pest alerts (Yigberemey et al, 2023; Barnett-Howell, 2021)
Market linkages (Hasanain et al, 2017)
Innovations to address multiple constraints at once (Deutschmann et al, 2021)
What have we learned?

Barriers to delivering more customized technologies and services to more farmers: A case of weather forecasts

Accurate, local forecasts can be highly profitable for farmers but currently unavailable

Technology to generate hyper local weather forecasts exists in the Global North

Private sector can’t fill the gap
- Large fixed costs in generating local forecasts
- Low marginal cost to deliver forecasts: Farmers’ low willingness to pay
- Not profitable unless there is a guaranteed demand

Governments can’t fix the problem
- Low resources; low capacity
- Incentive misalignment within a government
- National weather services are often political
What have we learned?
Potential for yield gain now and to 2050

Key messages:
- Farmers care about increasing profits and managing risks and uncertainties
- Returns and constraints to technology adoption vary widely across farmers
- Large potential yield gains from deepening customization of technologies and delivery

Immediate future: Scaling innovations that are shown to work for some farmers

To 2050:
- More locally suitable technologies and information in real time
- More innovations to help farmers figure out what is profitable, when & how to apply them
- More coordinated effort to overcome market, institutional, and political challenges to scale good ideas (e.g., pull financing) at the global level
Appendix: Experimental studies
Review of experimental evidence

- Bridle et al (2020). Experimental Insights on the Constraints to Agricultural Technology Adoption
- De Janvery et al (2016). The Agricultural technology puzzle: what can we learn from field experiments?
Alleviating credit constraints by itself generates large gains for only a small proportion of farmers

- **Agricultural loans:** Loan take-up varies from 17-33%; among those who take-up the loans, fertilizer adoption increases by 11-35% across four studies in Ghana, Morocco, Mali, and Ethiopia (Beaman et al, 2015; Karlan et al, 2015; Crepon et al., 2015; Tarozzi et al, 2015)

- **Cash grant:** Cash grants among small-holder farmers led to a 14% increase in fertilizer use, increasing profits by ~13% (Beaman et al, 2015).

- **Flexible loans:** Loans with different repayment times suitable for agriculture has shown to increase ag profits. For example, harvest-time storage loans significantly increased smallholders’ profits through temporal arbitrage, (by allowing farmers to hold on longer and sell only after prices rose) (Burke et al. 2017)
Risk-reducing technologies crowd in ag investments

- **Catastrophic pest attacks**: RS-based real-time blight alert helps potato farmers in Bangladesh to reduce losses due to blight and crowds in ag investments, leading to a **7% increase in yield** (Barnett-Howell, 2021)

- **Extreme weather events that destroy plants**: Free samples of flood tolerant seeds + information increase ag investments, leading to a **10% increase in yield in non-flood years**; sustained impact over multiple seasons (Emerick et al, 2016)

- **Pest/rodent infestation in stored grains**: Hermetic bags helps Indian rice farmers nearly eliminate postharvest loss from pests & rodents (10% of harvest) (e.g., Shukla et al, 2019)

- **Exogenous and easily observable shocks**: Index insurance has been shown to increase ag investments and profits when researchers are able to increase take-up, but take-up in natural settings is very low (Karlan et al, 2015; Boucher et al, 2022)

- **Unanticipated weather patterns over the course of the season**: Seasonal forecasts and short-range forecasts reduce labor costs and increase yield by 10% (Yigbemey et al, 2023)
Combination of risk-reducing technologies could offer multi-peril protection

- Farmers face MANY large risks throughout the season: A single-peril technology (especially for frequent and/or catastrophic risks) is helpful, but does not eliminate risks
- Technologies that address different risks could generate interaction (or “multiplier”) effects
- A 3-year study in Tanzania (Boucher et al, 2022)
  - Drought-tolerant (DT) seeds: resistant to mid-season drought
  - Multi-peril insurance: early-season rainfall deficit index + satellite-based area-yield index
  - Suggestive evidence that these risk-reducing technologies together
    - fully protected farmers from correlated yield shocks
    - helped farmers increase ag investments among those who experienced shocks
    - those who didn’t experience shocks disadopted these technologies
Agricultural extension can help farmers learn about new technologies; how information is delivered matters

- Farmers are more likely to follow advice from those that reflect their own characteristics, including demographic and socioeconomic characteristics (BenYishay and Mobarak 2014) and gender (BenYishay et al., 2016).
- Farmers are more likely to adopt the technology if multiple people in their social network use the technology (Beaman et al., 2015; Tjernström, 2017).
- Timely and actionable advice delivered via mobile phones increases the adoption of productive technologies (Cole and Fernando, 2021; Fabregas et al, 2023).
- Simple decision-support tools increase the adoption of complex practices: Leaf color charts increase fertilizer efficiency, increasing yields and profits (Islam & Beg, 2019).
Market inefficiencies are not only about access and price: quality uncertainty suppresses propensity to adopt technology

- A “Yelp”-like crowdsourced digital service to rate the quality of artificial insemination service providers in Pakistan improves the AI success rate by 27%, generating large income increases. (Hasanain et al, 2017)

- Uncertainty about seed quality suppresses agricultural investments and yield: simply informing farmers about the quality of modern varieties they are given to them increases investments, leading to a 50% higher profits. (Bulte et al, 2023)

- Training farmers how to identify high-quality hybrid maize seeds changes farmer’s input purchase decisions, increasing yield by 5% (Hsu and Wambugu, 2023)
Deeper customization can increase technology adoption and yield

- Customized fertilizer advice increase yields by 7% in Nigeria (Arouna et al, 2021), 10% in Ethiopia (Ayelaw et al, 2022); no yield impact found in India (Cole et al 2023)

- RS-based real-time blight alert helps potato farmers in Bangladesh to reduce losses due to blight and crowds in ag investments, leading to a 7% increase in yield (Barnett-Howell, 2021)

- Participating in One Acre Fund’s a program providing high-quality input on credit and agricultural extension increased adoption of recommended practices by 50-150% and yields by ~25% among maize farmers in Kenya (Deutschmann et al, 2021)