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Technological Advances to Improve Food Security: Addressing Challenges to Adoption

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Key Issues

- Despite expected increases in food production in developing countries, the number of people at risk of hunger is predicted to grow, especially in the world's poorest regions.
- Widespread use of advanced technologies and practices is critical to intensifying food production in an environmentally sustainable manner, but the situation for food-insecure smallholder farmers is exceptionally risky, making them averse to experimentation.
- Factors that affect technology adoption are complex and varied, requiring research combining natural and social sciences to understand how best to influence the uptake and sustained use of effective technologies.
- Research should focus on understanding farm-level, economic, and policy barriers to adoption to find the most promising innovations and explore which approaches most effectively drive adoption of combinations of agricultural practices and technologies.
- Modeling can help us predict technology adoption's implications for changes in land use and crop mix, impact on the prices of goods, the consequences for labor markets, the net impact on food security, and environmental effects. Further work with smallholders will contribute to a more nuanced understanding of how to support them in specific contexts and help refine models with robust localized data on interdependencies in the rural economy.

Ensuring a stable and healthful food supply for the world's growing population has become increasingly urgent, particularly in the face of climate change. Despite expected increases in food production in developing countries, the number of people at risk of hunger is predicted to grow, especially in the world's poorest regions, such as sub-Saharan Africa (Figure 1). Calls to address the problem have become insistent, underscoring that political will for action exists, at least at the global level.[1,2] As a starting point for further

[1] This publication is a substantially revised version of a blog post written by the first author for the Chicago Council on Global Affairs, which has granted permission for its use. The original post can be found at http://globalfoodforthought.typepad.com/global-food-for-thought/2014/05/commentary-using-science-to-drive-adoption-of-new-technologies.html.

[2] We use the term *technology* to encompass both technical innovations and changes in farming practices.

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research and discussion among policy makers, development practitioners, and researchers, this brief points to some of the complex factors related to adopting technologies that can address these challenges.

Technical innovations and improved farming practices that increase agricultural production and productivity while enhancing climate resilience exist. These include drought-tolerant seed varieties, drip irrigation, and the precision application of fertilizers and agrochemicals, as well as practices such as integrated pest management, conservation farming, and improved watershed and soil management, among others. However, getting these technologies into the hands of the farmers who will benefit most from them is not straightforward. Although technology is not a panacea, it is key to addressing the food production side of the food security equation. Increasing food production simply by using more—land, water, seeds, fertilizer, and pesticides—will not achieve the significant improvements in productivity necessary to advance the economic well-being of the food insecure. Equally important, the "more" approach is limited by the scarcity of resources and contributes to greenhouse gas emissions, deforestation and other environmental ills.[2] Hence, widespread use of advanced technologies and practices is critical to intensifying production in an environmentally sustainable manner.

If technology and improved farming practices are clearly valuable, why is it that poor smallholder farmers in food insecure areas of sub-Saharan Africa, Central America, and South Asia do not readily adopt them? Although farming, like all productive endeavors, entails inherent risks, the situation for food-insecure smallholder farmers is exceptionally risky, making them averse to experimentation. In addition to farm-level risks (Figure 2), rural populations who participate in markets—for their crops, agricultural inputs, farm labor, and/or for food to supplement their own production—expose themselves to additional risks associated with fluctuating prices. Miscalculations that would be absorbed by a wealthier farmer can result in destitution or even starvation for a subsistence farmer and her family.[3] On a practical level, the decision not to adopt a more advanced technology can be a risk mitigation strategy itself. For instance, more advanced hybrid seed varieties typically cost more and require the use of costly fertilizer—a significant investment that can be lost if the rains fail to come.[4]

The social, economic, and other factors that affect technology adoption are complex and varied, requiring research that combines natural and social sciences to understand how best to influence the uptake and sustained use of effective technologies. Research should focus on four areas where complex combinations of challenges inhibit adoption.

Figure 1a. Predicted change in crop production between 2010 and 2050: selected regions

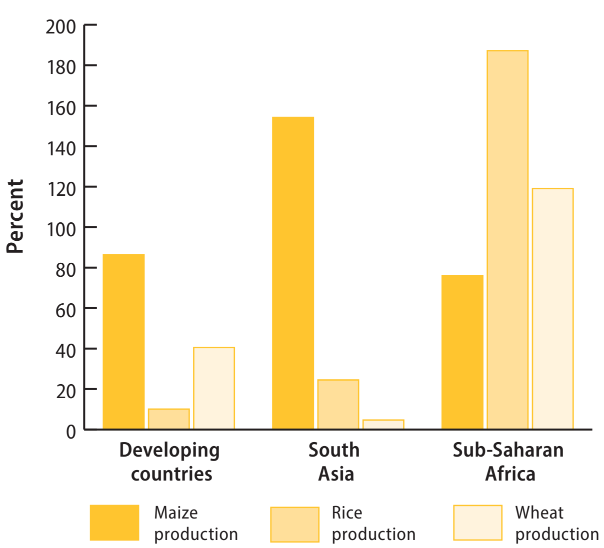
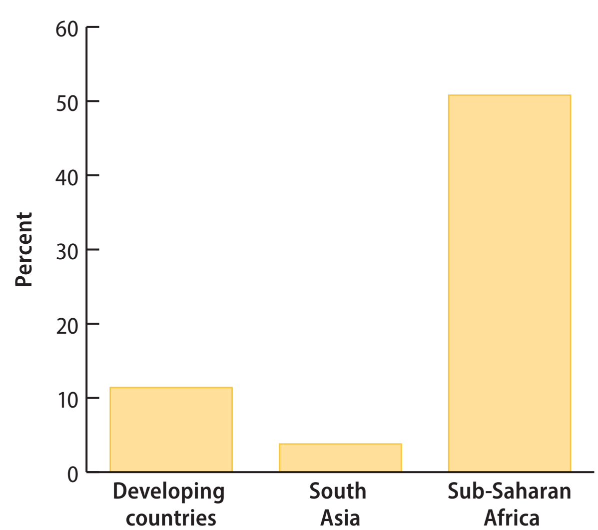


Figure 1b. Predicted change in the number of people at risk between 2010 and 2050: selected regions



Source: Adapted from Chapter 5 in Rosegrant et al.[18]

Note: Predictions assume greenhouse gas emissions based on rapid economic growth, midcentury peak in global population growth, development of efficient technologies, and balanced energy sources.

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Understanding (1) *farm-level*, (2) *economic*, and (3) *policy barriers* can illuminate where promising innovations may be viable. Further, researchers should explore which approaches most effectively drive adoption of (4) *combinations of agricultural practices and technologies*, rather than individual innovations in isolation.

Farm-Level Barriers

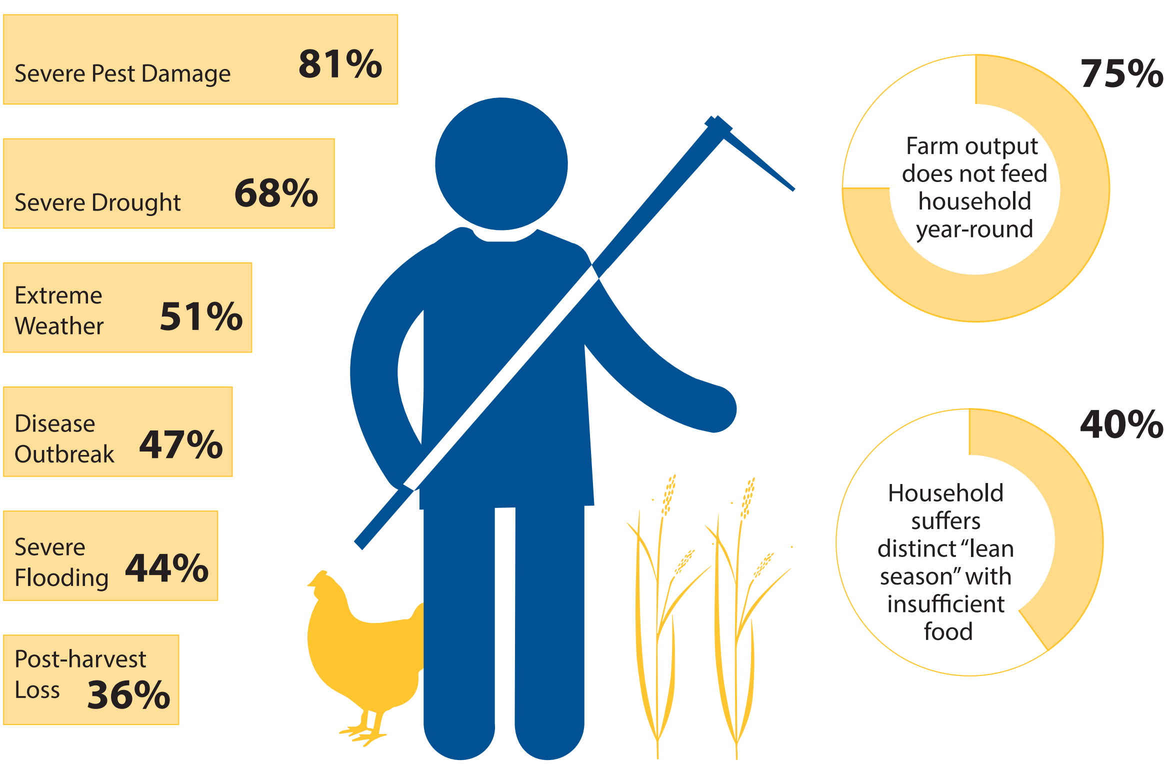
The high risks of switching technologies generally make farmers reluctant to shift away from established agricultural methods—such as traditional/saved seeds, traditional tillage, reliance on family labor, animal manure for fertilizer, and long-subsidized inputs—to test new practices and inputs. At the farm level, they may also face a range of specific constraints related to access to, use of, and awareness or availability of technological choices. Although studies exist that identify such constraints, more research is needed to inform programmatic approaches to facilitate adoption.

Research has shown that some types of farmers are especially unlikely to adopt new technologies. In addition to overall wealth and access to resources (such as household labor and nonfarm income), the age, gender, and education of a farmer can influence adoption.[4,5] In particular, women farmers often face constrained access to assets (e.g., land rights, bicycles) and inputs (e.g., labor, education, information, credit) that influence their technology choices. For instance, although Ghanaian cocoa farmers increased fertilizer use ninefold overall between 2002 and 2004, 42% of male farmers but only 25% of female farmers reported using fertilizer.[6]

Further, the characteristics of particular farms—such as water access, tenure arrangements, and plot size—can affect whether farmers switch technologies. Analyzing these characteristics is complicated because they may vary across an individual farmer's holdings and therefore not align well with households or farms as units of analysis.[7] For example, land tenure security has been shown to increase adoption of sustainable technologies,[8,9] because farmers expect to reap benefits from investments on owned land. Farmers who lack clear ownership—often women—must include loss of access to a plot as a risk when weighing investments in new technologies.[10] A single farmer may have different types of ownership arrangements for individual plots, leading to incomplete adoption of more productive technologies, even by receptive farmers.

Variation in adoption patterns has also been linked to differences in how information is effectively communicated and in the types of information that individual farmers can access. In general, improving access to education will facilitate

Figure 2. Farm-level risks facing smallholders, with reported averages for Madagascar, in percentage of farmers affected



Source: Adapted by authors from Harvey et al.[3]

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technology adoption,[5] but individual innovations may require more tailored approaches that account for farmer, farm, and technology features, as well as effective information channels. System technologies are often knowledge intensive and require local adaptation and experimentation to identify synergies between components.[7] Not surprisingly, research has shown that the quality of extension services matters greatly for facilitating adoption.[8] Flexible services that consider location-specific needs and priorities for improvement can help farmers reduce the risk associated with the experimentation needed for successful adoption.[7] Decentralized extension services that encourage local innovation may be best suited for some technologies, and centralized modes of extension more appropriate for others.[11]

Information gained through social networks is especially important for recent adopters of new technologies. However, segmented social structures and cultural barriers (religion, ethnicity, gender) can impede social learning and information sharing.[12] Extension services and social learning are often complementary, underscoring the need to take farmers' social networks into account to maximize the effectiveness of extension services.[13]

Economic or Market Barriers

An effective technology that is readily adopted in one setting may not be economically viable in another, even within similar agronomic zones. Research to identify market barriers to adoption must consider the full value chain, taking into account costs, market readiness, supply chains, and distribution partners.[14,15] Overlooking parts of the value chain when assessing feasibility can severely undermine the uptake of new technologies. For example, Abebe et al.[16] found that low adoption rates of high-yielding, disease-tolerant potato strains in Ethiopia were partly explained by consumers' preference for the taste of traditional varieties, highlighting the economic ramifications of social and cultural factors.

Commodity prices at local and national levels, as well as global trade flows, are predicted to shift with climate change, affecting the profitability of both existing and new technologies.[17] In addition to value chain research, modeling can help us understand patterns of climate variability and food security, as well as related market dynamics that can drive or inhibit adoption of specific technologies in particular regions.[18,19]

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Further, some technologies that have been shown to enhance sustainable agricultural intensification—for example, improved watershed management—have greater public than private benefits. Adoption of such technologies faces significant economic barriers, because farmers often do not reap visible, short-term gain from investments in them. For example, Rosegrant and his collaborators' models demonstrate that investing in drip and sprinkler irrigation produces small yield increases where those technologies are adopted but results in substantial water savings that can be applied elsewhere.[18] Research could suggest mechanisms to address such externalities and identify particular public investments that facilitate adoption of other promising technologies, such as improved watershed and soil management.

Policy Barriers

Policy can also inhibit adoption of new technology, both by driving up costs and/or by putting certain innovations out of reach. Adoption of proven new technologies may be stymied by policies such as subsidized inputs for existing technologies or mono- or oligopolies on inputs and outputs that constrain opportunities for change.[20] Weak protections for intellectual property and biotechnology policies can also hamper technological innovation and change. Elites benefiting from the existing agricultural system and institutional arrangements (including explicit and implicit subsidies) often resist technological shifts.

These constraints may be limited to specific locales, levels of government, or industries. For example, in Tanzania, 61% of subsidy vouchers are appropriated by village committees and elected officials.[21] In Ghana, the stable policy arrangement between the cocoa industry and the government—referred to as the "cocoa equilibrium"—particularly constrains prices paid to smallholders.[9]

Other political factors affect entire countries' prospects for adopting new technologies. In Ethiopia, the state controls the agricultural sector[22] and in Greece, "piecemeal policy frameworks and institutional rigidities" constrain technological change.[13] The Malawian government's political imperative to ensure food security has prompted seed and fertilizer subsidies and other government actions that exacerbate price instability.[23] Although strong policy frameworks and supportive government programs can facilitate broad adoption of innovations, fragmented or entrenched policies and programs skew technology choices and may distort market incentives for particular production systems as climate variability increases.

Feasible Combinations of Technologies

Although research has demonstrated that individual technologies can increase productivity in the face of climate variability,[16] farmers must consider innovations within the context of other practices. Further, effective technologies often involve combinations of innovations (e.g., improved fertilizer and hybrid seed[4]) or a set of practices (e.g., sustainable intensification[7,8]) that can be overwhelming to introduce at one time. More attention is therefore needed to identify effective combinations of technologies that are feasible for farm-level adoption in particular agro-economic zones. Such research should explore both how technologies interact and how they may be packaged or combined over time to facilitate adoption.

Such a focus will help us understand how innovations fit with current technologies and identify complementarities and substitutabilities between particular combinations of new and existing approaches. For example, integrated natural resource management and sustainable intensification practices have been demonstrated to increase food production and facilitate adaptation to climate change in several vulnerable zones.[8,24] Modeling by Rosegrant et al.[18] shows that combinations of traditional technologies with heat- and drought-resistant modern crop varieties can improve yields of corn, wheat, and rice. However, several studies have shown low adoption rates of integrated technologies,[7,8] in part because they are not readily affordable to smallholder farmers.[24] Longitudinal research is needed to trace patterns of adoption and rejection of combined technologies over time and to design schemes to facilitate technological shifts.[5,25]

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Conclusion

Although there is an existing body of research on the impact of specific, individual factors constraining technology adoption by farmers, understanding the full complexity of the situation is needed if we are to design programs that measurably increase the adoption of technologies and, more importantly, combinations of technologies that can sustainably increase production. Sophisticated modeling can map barriers at the farm, market, and policy levels and illustrate how they interact in different sociocultural and agro-ecological zones. Modeling at both macro and micro levels can help us understand better and predict the implications of technology adoption in terms of changes in land use and crop mix, impact on the prices of goods, the consequences on labor markets, the net impact on food security, and the effect on the environment. Such modeling may be particularly beneficial in understanding the adoption of technologies that contribute to public goods, such as improved watershed management or other climate mitigation impacts.

To complement models, we also need further work with smallholders to understand how to facilitate technology adoption and gather evidence on the agronomic, social, and economic barriers farmers face. Such efforts will not only contribute to a more nuanced understanding of how to support smallholders in specific contexts, but also help to refine models with robust localized data on interdependencies in the rural economy.

We should bring together natural and social science research to find combinations of technologies, market factors, and social and political forces that balance the needs of farmers and society at large. Science is creating the tools to solve food security challenges, but too many of them are locked in the barn. We need to use the full range of science at our disposal to ensure that these tools also get used in the fields.

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