Workshop Report:
Innovation for Vulnerable Farmers:
Drought and Water Scarcity Adaptation Technologies

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Innovation for Vulnerable Farmers: Drought and Water Scarcity Adaptation Technologies

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Abstract

This report is a summary of themes discussed during a two-day workshop on “Innovation for Vulnerable Farmers: Drought and Water Scarcity Adaptation Technologies.” The workshop was held at Harvard University on September 11–12, 2014. It brought together a diverse group of scholars to explore how actors in the agriculture innovation system can better promote the needs of small and marginal farmers.

Three key themes emerged from the workshop:

(1) Drought sets fundamental limits on productivity. Its impacts are intertwined with temperature and nutrient stresses. Both genetic and management options to mitigate impacts of drought exist, but there are no silver bullets. Moreover, many existing technologies for addressing drought and water scarcity are currently not in widespread and sustained use across many parts of the developing world.

(2) Agriculture technologies should be thought of in terms of risk profiles to farmers rather than yields. This mirrors how farmers themselves think about whether to adopt a new technology. In this context, packages of technologies, as opposed to stand-alone interventions, are often important. So are broader institutional interventions that mitigate risks to farmers and facilitate adoption such as access to assured markets.

(3) Successful innovation is a multistage process, generally involving invention, selection, promotion, adoption, and adaptation on the way to widespread use. The actors in the innovation system who are most concerned with serving the needs of small and marginal farmers too often focus only on one stage of the innovation system, missing other important stages that are necessary to achieve their ultimate goals. A broader perspective that encompasses the entire innovation system is needed.

(4) Efforts are needed to increase the involvement of small and marginal farmers throughout the stages of the innovation system. In order to do this we need to build local capacity to adapt knowledge and technologies to specific social and ecological conditions and develop social capital among small and marginal farmers to demand policies and technologies that meet their needs. A common theme connecting examples of success was the role of local champions, who often approach challenges from a systems perspective, connecting stages of the innovation system to help develop “pockets of prosperity” for small and marginal farmers in specific regions.

Keywords: agriculture innovation systems, drought, small farmers
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Sustainability Science Program

The Sustainability Science Program at Harvard University harnesses the University’s strengths to promote the design of institutions, policies, and practices that support sustainable development. The Program addresses the challenge of sustainable development by:

• advancing scientific understanding of human-environment systems;
• improving linkages between research and policy communities; and
• building capacity for linking knowledge with action to promote sustainability.

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Innovation for Vulnerable Farmers: Drought and Water Scarcity Adaptation Technologies

Report of a Workshop held at Harvard University, September 11–12, 2014

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Introduction

This report summarizes themes discussed during a two-day workshop on “Innovation for Vulnerable Farmers: Drought and Water Scarcity Adaptation Technologies.” The workshop was held at Harvard University on September 11-12, 2014, under the sponsorship of the Sustainability Science Program at Harvard’s Kennedy School of Government.1

The goal of the workshop was to explore key challenges in the innovation system for drought and water scarcity adaptation technologies intended to meet the needs of small and marginal farmers. The focus on poor and marginal farmers was adopted to move the dialogue around water and agriculture away from questions of yield or water-use efficiency and towards the challenge of serving the needs of the most vulnerable members of our global agricultural system. In particular, the workshop aimed to:

1. Provide a space for interdisciplinary discussion between different communities, including both scholars and practitioners across a wide variety of disciplines relevant to agricultural innovation and adaptation to drought and water scarcity.
2. Create a holistic understanding of the current innovation system for drought adaptation technologies for vulnerable farmers by synthesizing knowledge across a wide variety of technology categories and stages in the innovation system.
3. Diagnose weaknesses in the innovation system for drought resistant technologies relevant to the livelihood of vulnerable farmers.
4. Identify strategies for addressing key barriers in the innovation system with respect to the needs of the most vulnerable farmers.

To achieve its goals, the workshop brought together a diverse group of scholars from many countries and organizations (see appendix A for full list of participants). Participants were keenly aware that agriculture systems today are facing many challenges, both old and new. These include increasing demands for food caused by population growth and changing consumption patterns, environmental stress resulting from climate change, increased incidence of droughts and floods, re-emergence of virulent pest varieties, land degradation, insecure land tenure for many small farmers, and so on.

In agriculture systems technological innovation plays a central role in allowing people to adapt to challenges and changing circumstances. The application of knowledge and technology to farming defines modern agriculture systems and is central to improving yields, reducing environmental impacts, and improving the well-being of farmers across all types of agriculture systems. Over the 20th century, growth in agriculture output was driven by investment innovations in science and technology. New technology for staple crops, such as wheat and rice, resulted in yield improvements that shifted the dynamics of global agriculture systems and allowed for growth in global output of staple crops without a corresponding increase in cultivated land (Ruttan 1977, 2001).

The history of the Green Revolution and the emergence of the CGIAR is a familiar example of a goal-oriented innovation system designed to meet the needs of a rapidly expanding global population. These efforts contributed to the development of new technologies and supported the widespread use of those technologies through policies that incentivized adoption and capacity building activities (Sagasti and Timmer 2008).

1 Workshop web page <http://www.hks.harvard.edu/centers/mrcbg/programs/sustsci/events/conferences-and-workshops/2014/aginnovation>. We would like to give a special thanks to Nora O’Neil and Stephanie Hillsgrove for their invaluable organizational support before, during, and after the workshop. In addition, we are thankful to the logistical support of Jessica Gard, and Deni Peric.
Yet more than fifty years after the Green Revolution was launched, substantial agricultural productivity gaps between and within countries persist, as does the continued poverty of small and marginal farmers in many parts of the world. This suggests that the current agriculture innovation system is not fully meeting the goal of improving the well-being of small and marginal farmers. The past century’s transition towards yield improving technologies occurred as a patchwork of successes and failures around the world (Foley et al. 2011). In particular, many of the poorest regions in the world (such as sub-Saharan Africa) have lagged far behind global yield trends (Cassman and Grassini 2013). The poorest and most marginalized farmers globally have often been excluded from opportunities to improve their yields and enter into new high value markets.

Why is the current agriculture innovation system not able to provide technologies that meet the needs of small farmers? While some argue that the problems are due to most science and technology expertise now residing within private companies, others blame the challenges on the weariness of the international system to support large-scale ventures such as the Green Revolution (Pardey and Beddow 2013). A key point—and the motivation for this workshop—is that this is an analytical question. We need to analyze, rather than assume, how and why the innovation system is functioning (or not) to meet sustainable development goals, especially providing improved livelihoods for impoverished small farmers.

In order to shed light on the motivating challenges described above, the workshop was organized around five panels addressing specific questions that together spoke to the overarching theme of the workshop. Following each of the panel presentations, all workshop participants engaged in a discussion and sought to further clarify answers to the questions before the panel.

Panel I: What are the major challenges? What are the major challenges facing vulnerable farmers in adapting to drought and water scarcity?

Panel II: How well are we doing? How well is the agriculture innovation system doing in meeting the challenges faced by vulnerable farmers in adapting to drought and water scarcity?

Panel III: Why are we not doing better? Why are we not doing better in orienting the innovation system for drought adaptation technologies to meet the needs of vulnerable farmers?

Panel IV: How could we do better? What are strategies for moving beyond simply identifying single barriers (or solving isolated problems) to systems-level solutions that will make the innovation system more responsive to the needs of vulnerable farmers?

Panel V: What should we do next? By this point in the workshop, we hope to have developed a common understanding and systems perspective of the barriers and bottlenecks to improving the agriculture innovation system to meet the needs of the most vulnerable farmers in adapting to drought and water scarcity.

This report summarizes the main themes in each panel from the workshop. The workshop was off the record and participants spoke on behalf of themselves and not their organization in order to allow for an open and frank discussion. No direct attribution is given to any individual viewpoint in the workshop report.

We are grateful to all of the participants for their contributions to the workshop as well as their insightful feedback on the workshop background paper sent out in advance.
Conceptual Framework

The workshop’s conceptual framework emerged from an ongoing interdisciplinary research project on “Innovation and Access to Technologies for Sustainable Development” that the Sustainability Science Program at Harvard has been conducting since the fall of 2011. The project employed an inductive approach to study the challenges of “innovation and access to technologies for sustainable development” (Diaz Anadon et al. 2014). The project resulted in a conceptual framework for systematically investigating a goal-oriented innovation system. The conveners of this workshop offered this conceptual framework as a tool for structuring the workshop.

Innovation for poor and marginal populations faces many barriers, but achieving the goals of sustainable development requires that new knowledge and technology appropriate to the conditions of poor and marginal farmers be invented whether in laboratories or in farmers fields; selected, whether by private companies, state extension services, or NGOs; produced, whether by governments, private companies, or other actors and groups of actors; adopted, whether by farmers themselves or, in the case of supporting infrastructure, by governments and other entities; adapted, whether by farmers, other actors in the innovation system, or a partnership of both; and finally put into widespread use. In addition, obsolete technologies where more sustainable alternatives exist must be retired, which

Definitions: Creating a common language

**Vulnerable farmers**: We define vulnerable farmers as individuals or groups of farmers that are “not resilient” to external shocks in socio-economic or biophysical conditions; rapid changes in these conditions are likely to push these farmers into a downward spiral with negative impacts on their well-being. These farmers are vulnerable to a number of external shocks (e.g., drought). Their vulnerability to these threats stems from the fact that they are often significantly below the poverty line, have small landholdings and insecure tenure, lack social safety nets, and/or are otherwise food insecure. Often, the precise characteristics that define small and marginal farmers are context dependent with large variation between and even within countries.

**Technology**: In this project we adopt Harvey Brooks’ definition of technology as “knowledge of how to fulfill certain human purposes in a specifiable and reproducible way” (Brooks 1980). In the agriculture sector this includes biotic, manufactured, and methods-based technologies.

**Innovation**: Again we begin with Brooks’ definition: “the process by which technology is conceived, developed, codified, and deployed” (Brooks 1980). An innovation system describes more than the processes of technology invention, rather a complex system that includes invention, selection, production, initial adoption, adaptation, sustained use, and retirement must all be considered in the study of innovation.

**Intuitions**: Rules and norms, which are “the humanly devised constraints that shape human interaction” (North 1990).

**Actors**: Individuals or organizations with agency in a complex system, capable of either perpetuating “business as usual” or promoting changes in a system.

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often requires sustained engagement on the part of many actors in the innovation system to overcome the status quo, by compensating losers in the transition or supporting new technologies through subsidy programs and capacity-building activities.

The conceptual framework for studying goal-oriented innovation systems developed by the Sustainability Science Program has a theoretical foundation in the fields of innovations systems, complex systems and system dynamics, science and technology studies, the economics of innovation, and global governance. It also drew on 18 case studies conducted by the project across five sectors (agriculture, energy, health, manufacturing, and water) to inductively develop a model of the innovation system. The conceptual framework is as a non-linear system of knowledge and technology stocks. The stocks are linked by stages and specific mechanisms link technology stocks and allow technologies to “flow” through the stages. Mechanisms differ both based on the characteristics of the technology itself and the social and natural aspects of the environment in which the technology is deployed. The stocks in the model include: (1) knowledge, (2) inventions, (3) feasible technologies, (4) technologies in limited production/use, (5) technologies in widespread production/use, and (6) obsolete or retired technologies. The stocks are linked by seven stages: (a) invention, (b) selection, (c) production, (d) early adoption, (e) widespread use, (f) adaptation, and (g) retirement. In this framework the “flow” of technology between stocks is enabled by different mechanisms that differ both across attributes of the technology itself as well as the social and environmental system(s) conditions. (See appendix D for conceptual model of the innovation system.)

The conceptual framework presented in this paper provides a tool for approaching questions in innovation studies through a structural model that ensures innovation is investigated as a complex and patterned process, instead of being treated as a black box through which knowledge and technology suddenly appear as fully constituted objects. By “unpacking” the innovation process into stocks and stages connected by mechanisms, scholars can more clearly identify the mechanisms by which technology moves from basic research to widespread production and use, as well as the barriers to this process.

Panel 1. What are the major challenges?

The first panel set the stage for the workshop, exploring the major challenges facing vulnerable farmers in adapting to drought and water scarcity. Panelists included both natural scientists and practitioners.

The panel began by underscoring the importance of water to plant growth and the fundamental relationships between transpiration rates, water availability and photosynthesis. The panel emphasized that under conditions of water scarcity there are limits to plant productivity. However, despite these fundamental constraints, there are both management options (e.g., irrigation; soil mulching; species selection; improved cropping methods such as no-till) as well as genetic options (e.g., varietals that reduce water use or access more water though larger root areas) that can help farmers adapt to conditions of drought and water scarcity.

Panelists spoke to the importance of being specific when studying drought and water scarcity. Drought is a term that covers a broad range of circumstances. From a research or farming perspective, a more nuanced understanding of specific types of drought and water scarcity is needed to diagnose challenges or plan for interventions. Panelists noted that in the field every year and in every crop there are new conditions that characterize the specific type of drought or water scarcity impacting plants. Panelists suggested that drought and water scarcity should be thought of in terms of stress to plants. Important questions to answer for research and practice include: what kind of
stress will the plant be under, and at what point in the cropping cycle. The panel also noted that heat stress, which often accompanies drought, makes it difficult to isolate the factors that are actually harming plant productivity in a given case. It is also possible to mistake nutrient deficiencies for problems caused by drought and water scarcity, underscoring the importance of field-level expertise and soil testing to understand the productivity barriers at the plot level. Understanding the interlinked challenges of water scarcity, heat stress, and soil fertility is important to consider when developing both management and genetic tools for overcoming water scarcity.

Panelists noted that in addition to the development of new biotic and manufactured technologies, improved practices have significant potential for closing yield gaps especially for small and marginal farmers. For example, a major cause of risks associated with drought and water scarcity has been the transition from multi-cropping systems to single-cropping systems. Changing farming practices to include multi-cropping methods can help increase resilience to drought and water scarcity at the farm or village level.

The panel spoke to the social and organizational challenges involved in orienting agriculture innovation systems to small and marginal farmers. Three specific challenges were highlighted:

1. Lack of involvement of small and marginal farmers throughout the stages of the innovation system.
2. Lack of local capacity to adapt knowledge and technologies to specific socio-environmental conditions and the needs of small and marginal farmers.
3. Lack of the social capital among small and marginal farmers that would allow them to demand government policies that meet their needs.

Issues of gender in the context of smallholder agriculture were also highlighted as important challenges for agriculture innovation systems. In particular, panelists noted that land at the household level is often divided between men and women, with woman having access only to poorer quality lands. Thus researchers and development practitioners need to ask in a given region whether we are addressing challenges that are faced specifically by women farmers. By failing to speak with women farmers and understand their needs, development practitioners and other actors often fail to meet the needs of women farmers. This point highlighted the need to move studies beyond the plot to the farm or village level in order to capture systematic inequalities and ensure that innovation systems do not serve to further entrench these inequities.

The panel noted that funding for food aid often far exceeds funding for agriculture development. This points to the need to reorient food aid towards improving the resilience of local food production in order to generate local economic growth and overcome long-term food insecurity. Small and marginal farmers do not only need improved yields for staple crops such as rice and wheat, they also need improved access to nutritious food such as fruits and vegetables. Policies should focus on nutritional rather than only caloric security of the food supply.

The overall conclusion of the panel was that the most critical challenge in the agriculture innovation system for drought adaptation technologies is getting existing technologies into widespread adoption and use.

The discussion following the panel presentation highlighted several additional challenges about how to better orient the innovation system around drought and water scarcity so as to meet the needs of vulnerable farmers. One major question that was raised was how to prioritize research areas and measure impacts. The metric of return on investment was criticized because it lacked focus on to whom the return on investment accrued: How do you ensure that you aren’t just focusing on average returns but are including equity concerns by tracking actual returns to small farmers. The panel noted a dearth of studies that discuss either methodologies or case studies for measuring
returns on investment to small farmers. Most studies—especially those at larger scales—look mainly at yield or income improvements but say little about how the gains from these improvements were distributed across categories of farmers.

Barriers to adoption were highlighted in the discussion as another key challenge. Breeding programs have the capacity to turn out new crop varieties in 7–8 years. But small and marginal farmers are frequently not adopting these technologies. For example in Kenya the most popular maize hybrid is 30 years old. So even if the research community is developing varieties that respond to drought and water scarcity, this doesn’t help small farmers if the new varieties are not being adopted in the field. An associated problem is the uncertainty on the part of scientists regarding the different types of drought stress that are currently occurring or will occur as a result of climate change. This uncertainty means that scientists do not know exactly what kinds of traits they should be breeding for.

Another challenge brought up in the discussion was labor shortages. While in Asia population densities generally mean that labor is in abundant supply, in much of sub-Saharan African productivity at the farm level is limited by insufficient labor to crop the entire area available to an individual farmer. Potential technological solutions should thus also be evaluated on labor dimensions. This discussion underscored the importance of findings from the literature on induced innovation that different types of technologies may be suitable in different areas based on the criteria of labor abundance vs. labor scarcity. Even in a single country, different farmers may face very different opportunity costs with respect to their own labor and as such may find different technologies more suitable to their needs.

The role of power, especially in situations of drought and water scarcity, was raised as a significant causal factor behind challenges facing small and marginal farmers adapting to drought and water scarcity. In particular, in situations where an essential resource (e.g., water) becomes scarce, those with more power are more likely to capture more of the resource. This is especially true in irrigated rather than rain-fed areas. One participant spoke about political upheaval she observed in many development projects in arid and rain-fed regions, caused by unforeseen distributional impacts of development interventions on water resources and access to water. This discussion highlighted the importance of focusing beyond the farm and at the broader institutional and political environment when studying the challenges associated with orienting innovation systems towards the needs of small and marginal farmers.

Panel 2: How well are we doing?

The second panel addressed the question how well the agriculture innovation system is doing in meeting the challenges faced by vulnerable farmers. In particular, panelists were asked to identify successes and failures of the agriculture innovation system in meeting the challenges facing vulnerable farmers. Specific focus was given to what the system is doing well and for whom? And what the system is doing poorly and for whom?

The panel began with a case study on micro irrigation systems (MIS) in India. In India, adoption of MIS, supported by a nation-wide subsidy program, is growing quickly. But the total irrigated area covered by MIS is only 8%. The panel highlighted how the success of MIS in India is supported by government subsidies ranging from 40–90% of the technology cost. Private MIS companies have also played an important role in the success of drip irrigation by helping farmers overcome financial barriers through provision of easier access to loans. And by mitigating the risks faced by farmers when investing in technology by creating contract-farming arrangements (notably for mango and onion) ensuring farmers a minimum level of profit from their crops when grown with MIS.
technologies. These synergies between the public sector financial support and the engagement of private companies in helping farmers overcome the major barriers to adoption have led to many “pockets of prosperity” where widespread adoption of drip irrigation technology has had substantial impacts on the well-being of Indian farmers—states like Andhra Pradesh, Gujarat, Maharashtra, Tamil Nadu and Telangana are all have many examples of such “pockets of prosperity.” However, other states in India have seen negligible adoption of MIS indicating that such “pockets of prosperity” are difficult to replicate and scale. The panel also noted that the success of MIS in India did not happen over night. India began experimenting with MIS in the late 1990s and only within the last 5–10 years have adaption rates begun to take off.

The panel paid specific attention to sub-Saharan Africa. There, productivity increases lag far behind those of the rest of the world. Large swaths of agriculture land are in drought prone areas. Other areas suffer from economic rather than physical water scarcity as farmers lack the infrastructure to access water (e.g., through irrigation canals or electrically powered tube wells). Water scarcity driven by economic rather than physical factors highlights the need for improved irrigation infrastructure in sub-Saharan Africa. At present, however, only 5% of sub-Saharan Africa is irrigated. Governments face significant institutional barriers as well as a lack of local knowledge and capacity, which hamper efforts to expand the irrigated area. Small-scale irrigation schemes are also overlooked by donors and should receive greater support for their potential to help small and marginal farmers. The panel saw the lack of support for small-scale irrigation systems as a major barrier in the innovation system for small farmers.

There is a long-standing tension between input heavy technologies created by external experts and input light technologies often created by farmers themselves and popularized more widely by NGOs and other actors. In Bihar (a state in northeast India), the adoption of a set of practices for managing the plants, soil, water, and nutrients in rice farming—referred to as system of rice intensification (SRI)—has taken off rapidly in the past seven years. Bihar is one of the poorest states in India with a population of 103 million people and over 93% small and marginal farmers. Since SRI was introduced in the state in 2007, the number of adopters has reached approximately 2 million farmers. One of the reasons highlighted for the success of SRI was its lack of input intensity but also strong support both from local champions and the state government. In 2011 the state government included SRI as one of the main technologies for promotion in their agriculture road map, providing a mandate for the agriculture department to promote SRI through extension services as well as a subsidy package to incentives farmers to adopt SRI. In addition, the development of supportive technologies, in particular weeders and seed drills, helped farmers adopt SRI methods. Farmers in Bihar have reported significant gains from SRI including longer periods of food self-sufficiency, increased cash income, and reduced expenditures on seeds and fertilizers. At the same time, there are reports of disadoption, especially among farmers who receive subsidy incentives but lack sustained support from extension agents or NGOs in the knowledge-intensive practices. While tensions about the efficacy of SRI vs. other approaches to increasing productivity have not been resolved, what is clear is that in Bihar, close cooperation between NGOs and the government helped to achieve widespread use in a short time of a new practice-based technology by small and marginal farmers. Bihar thus offers important insights into how to scale practice-based technologies through collaboration between public and NGO sectors.

The discussion following the panel presentations highlighted the challenges of measuring impact and success in order to understand how well we are doing across different scales. Several comments mentioned that due to pressure on organizations to report success stories, there is a lack of opportunity to catalog and learn from failures.

The discussion also noted that many technologies are designed for larger and wealthier farmers, while the majority of farmers in many parts of the world are small and marginal farmers. Even when
technologies are adapted to developing world contexts, they are often only useful to larger farmers with sufficient assets to take on risk. The importance of thinking about agriculture technologies in terms of risk profiles to farmers rather than yields was a repeated theme. It was argued that this is how most farmers themselves think about whether to adopt a new technology and that other actors in the innovation system should do a better job of thinking like a farmer.

The challenges of widespread adoption, especially adoption by small and marginal farmers, were central to the conversation. While the participants resonated with the “pockets of prosperity” discussed by panelists, there was general agreement that moving from pockets of prosperity to widespread success is extremely difficult. Questions were raised about the characteristics of technologies themselves that are more or less amenable to achieving widespread use (e.g., capital intensity, input based, methods based), as well as the varied capacity of the public, private, and civil society sectors to promote adoption and widespread use. For example, new cropping practices that reduce inputs through more knowledge intensive technologies have a different risk profile than technologies that require large upfront expenditures. Technologies targeted at small and marginal farmers should be indexed in terms of risk profiles along a range of criteria that take into account the characteristics of the technology itself as well as the social-environmental system in which the technology will be used. A better understanding of the risks faced by farmers in adoption of new technologies will enable other actors in the agriculture innovation system to support technologies that meet the needs of small farmers.

The discussion noted the importance of thinking about tradeoffs between promotion of technologies with subsidies and macro-level policies vs. field-level training and knowledge support. There was some consensus that the relative merits of these two approaches to promoting adoption differed both by type of technology and by the types of farmers you aimed to reach. In general, for small and marginal farmers a combination of subsidies with robust field-level support seems to be the best practice for supporting adoption. The capacity of actors in the innovation system to provide this support at scale is, however, limited.

Participants noted that many examples of success raised in the discussion included packages of technologies as opposed to single stand-alone interventions. Achieving the pockets of prosperity usually required more than one technology as well as broader institutional conditions that mitigated risks to farmers and facilitated adoption such as access to assured markets. Another element of most success stories was the existence of a local champion. But local champions are not always available, and there is little consensus on how to identify local champions ex-ante. One participant with significant field experience in government extension told his new employees that over the course of their career they would be doing well if they were able to find and work closely with 5–7 excellent local champions. In his opinion most often lead farmers self-identified themselves to extension agents as effective local champions.

Participants discussed the overall usefulness of an innovation systems perspective for analyzing the large number of cases of both successes and failures in improving the well-being of small and marginal farmers. Participants highlighted that an innovation systems perspective is useful as a diagnostic tool in order to make comparisons and generalization and identify barriers at the systems level. Participants generally felt that the innovation systems concept was less useful as an “ideal type” towards which agriculture systems should strive.

The major conclusion from the second panel was that while there are certainly “pockets of prosperity” where the innovation system is functioning well to serve the needs of small and marginal farmers, for the most part scaling-up success stories to serve more farmers is not easy. Major challenges remain including the lack of on the ground champions who are usually key figures in the
success stories we do have, as well as the limited capacity of the private sector to engage with small farmers, especially in more remote areas.

Panel 3. Why are we not doing better?

The panel began by underscoring the findings of panel 2: While many technologies exist to help farmers adapt to drought and water scarcity, these technologies are only gaining widespread use in certain “pockets of prosperity;” widespread adoption amongst small and marginal farmers remains a fundamental challenge. The panel addressed the major barriers and bottlenecks preventing the innovation system for drought and water scarcity adaptation technologies from functioning better to meet the needs of the most vulnerable farmers.

The main theme that ran throughout the panel was the importance of paying more attention to risks faced by small and marginal farmers in evaluating the potential of knowledge and technology to help them. In the agriculture innovation system, technologies are often promoted on the basis of productivity rather than the ability to mitigate risk. This fundamental flaw hampers the ability of the agriculture innovation system to meet the needs of vulnerable farmers who cannot afford failure.

One strategy for finding knowledge and technology that reduces risk for vulnerable farmers is to pay more attention to farmers’ own creative coping strategies. By observing farmers’ own strategies, researchers can better understand the relationship between knowledge and technology adoption and farmers’ own nuanced perception of the risks they face. Understanding farmers’ coping strategies requires more on-farm research and experiments with a specific focus on risk across multiple criteria. These must include environmental dimensions of risk (e.g., droughts, water scarcity, pests, etc.) as well as social ones (e.g., land tenure security, assured markets for crops, etc.).

The importance of small-scale technologies that improve yields or reduce labor inputs without large and risky up-front capital outlays was highlighted. Often these inexpensive innovations can be found not in laboratories, but in the fields of innovative farmers themselves. For example, the Honey Bee Network in India has helped to identify and scale many such low-cost solutions originating in the fields of local innovators. Outside actors can play an important role in helping technologies invented in one location gain widespread use. They do so in part by creating an institutional environment for promotion and production of local inventions, which are often overlooked by traditional agriculture development actors.

The panel discussed three theories or assumptions that often come up to explain technology adoption by farmers:

1. Water scarcity will induce the adoption of water saving technologies.
2. Putting a high price on water will induce the adoption of water saving technologies.
3. Farmers require access to and information about water saving technologies (scarcity and high water costs alone are not enough).

These assumptions were studied in the case of Gujarat, India. The first assumption was found to be incorrect in the Gujarat context as, in the face of rising water scarcity, farmers dug deeper wells and reduced cultivated area but did not adopt water saving technologies. Likewise, the second assumption proved incorrect in the context of Gujarat because farmers did not reduce water consumption in response to monetary incentives provided by researchers. Moreover farmers expressed to researchers that they could not reduce their water consumption because they did not know how. Finally, when researchers tested the third assumption that farmers needed access and information about water saving technologies, they found that the provision of information combined with the institutional policies to support drip irrigation in Gujarat promoted adoption of the technology. In particular, strong subsidies for drip irrigation technologies helped farmers overcome up-front capital costs and
created an institutional framework that gave farmers information about drip irrigation technologies as well as the ability to access the technologies.

The panel also discussed changes that the research community should make to more efficiently target their research to vulnerable farmers:
1. More field-based research because plants grow differently in the field than in research stations under controlled conditions (e.g., the progression of drought stress is slow in rain fed rice and fluctuates depending on erratic weather patterns).
2. Focus more on traditional plant breeding and less on transgenic crops, because traditional breeding is still the most effective way to develop new improved germplasm to meet specific needs.
3. Higher priority should be given to impact on farmer livelihoods (as opposed to prioritizing intellectual property rights and publications in high impact journals).
4. Better policies and guidelines at national and regional scales to disseminate drought tolerant seed varieties and other drought and water scarcity adaptation technologies to farmers.

Finally, the panel addressed systematic failures of the agriculture innovation system to think beyond the scope of single technologies, crops, or regions. It stressed the need to think about technology as a transformative function that converts other assets (land, water, labor) into improved well-being of farmers. When technology is reframed as a transformative function for improving well-being, management systems based around multiple technologies supported by interlinked institutions appear to be a more appropriate lens of analysis both of barriers in the agriculture innovation system as well as potential solutions. A management systems approach acknowledges that farmers do not live in isolation from larger socio-ecological contexts and that appropriate technologies should be studied within these contexts and at multiple scales.

The discussion following the panel presentation continued on the theme risk and the importance of a risk-based approach to analysis of agriculture technology for vulnerable farmers. Both research and practice should aim to provide technological and institutional solutions that mitigate the risks vulnerable farmers face. However, evaluating risks is not easy or straightforward. Long-term longitudinal data is needed to build probability curves that allow research to properly model the risks farmers face in a given area. Modeling risks in the future is further complicated by climate change and the uncertainty of long-term trends in social and environmental systems.

Some methodologies and solutions for reframing agriculture research and development practice around issues of risk include:
1. Scaling up adaptive management and a portfolio approaches to agriculture knowledge and technology.
2. Improving feedback mechanisms and linkages between stages of the innovation system.
3. Increasing focus on understanding and promoting farmers own technologies and strategies for improving well-being in the face of risk.

Other systematic failures of the agriculture innovation system to meet the needs of small farmers raised by participants include:
1. Failure to address challenges created by politics and power.
2. Extensive corruption limiting many countries’ agriculture departments and extension systems.
3. Capture of benefits from agriculture innovation policy by larger farmers through lobbying and other mechanisms.
In response to these challenges participants raised the potential of finding synergies between the interests of small and larger farmers in commodity systems. Some businesses have successfully pursued the integration of small farmers into larger commodity systems as a strategy with benefits for both small farmers and industry. The scalability of this model beyond isolated “pockets of prosperity” has not, however, been demonstrated to the knowledge of the workshop participants.

Participants noted that many of the systematic barriers raised in the discussion were not new to the research community. Yet despite continued identification of these barriers, there is still a failure of the agriculture innovation system to meet the needs of small farmers. Participants suggested that if we thought of the activities of public sector and international civil society as a business, the business would be failing. Underscoring this point, participants noted that when a European donor gave money directly to farmers groups for funding agriculture research, farmers chose to fund something completely different from what researchers were focused on. Moreover, the panel noted that in the Netherlands and Australia farmers play active roles in directing the focus of their countries’ national agriculture innovation policies. The panel suggested that other national-level innovation systems could learn from the examples set by these two countries.

Finally, participants debated the fundamental issue of what the goals of agriculture research and development should be. Some argued that there is no future for small subsistence agriculture. In this view, rather than focusing on on-farm livelihoods improvement technologies for vulnerable farmers, the research community should focus on how to transition small farmers out of agriculture. The importance of providing better educational opportunities was highlighted as an important mechanism both for improving technology adoption and moving small farmers out of agriculture. However, other participants felt that poverty alleviation through agriculture—at least in the short term—remained essential for the well-being of 500 million small farmers who currently are unable to move into other sectors. This debate highlighted conflicts and tradeoffs between increased agriculture productivity, poverty alleviation and environmental conservation. The issues raised proved divisive and there was no immediate consensus, mirroring debates over efficiency versus equity concerns in development policy more broadly.

**Panel 4. How could we do better?**

On the second day of the workshop the fourth panel discussed strategies for moving beyond simply identifying single barriers to systems-level perspectives for improving the performance of the innovation system to meet the needs of vulnerable farmers.

The panel began by discussing four key strategies to improve the agriculture innovation system:

1. The research and development community should learn from the past by fostering a shared understanding of successes and failures instead of constantly re-creating the wheel. Focusing on what went wrong rather than what went right, as well as gathering longitudinal data are both necessary steps to do this. As an example, the panel felt that many of the principles of climate smart agriculture are a repackaging of soil and water conservation methods of the 1990s. Proponents of climate smart agriculture should revisit the earlier literature before conducting their own work.
2. The research and development community needs to work harder to address farmers’ actual problems as opposed to our perceptions of their needs. Institutional changes that ensure demand-driven research are required.
3. The research and development community must be more forthright about the validity of their findings. In particular, both quantitative and qualitative results have their drawbacks.
Quantitative data is often of low quality, whereas in qualitative interviews farmers often tell researchers only what they want to hear.

4. The research and development community should practice humility, by both admitting and learning from failure and by recognizing the limitations of their perspectives and solutions.

The panel also discussed reforms in research culture that are important for improving the contribution of basic research to agriculture innovation systems. In particular, funding priorities should be changed to encourage high caliber social science efforts to understand barriers and solutions within agriculture innovation systems. The panel found that very few grants in the funding database of the United States Department of Agriculture National Institute of Food and Agriculture (USDA NIFA) are targeted at the social sciences. Moreover, academia needs to restructure its reward system, including prioritizing policy briefs and stakeholder involvement as part of criteria for deciding promotion and tenure. In addition, research needs to be open access in order for it to have widespread impact.

The panel highlighted the fact that solutions to on-farm problems can often only be found beyond the farm gate and are caused by larger institutional and political challenges. Moreover, problems are often interconnected. Institutions and technologies must therefore co-evolve to create an enabling environment for adoption and widespread use of knowledge and technology in farming systems. A tested strategy for ensuring this co-evolution involves innovation platforms, which engage multiple actors and ensure interactions throughout the value chain. One example of a successful innovation platform is the East Africa Dairy Development (EADD) program started in 2008. The platform links many actors to address constraints in markets, logistics, cold storage, artificial insemination technologies and practices, among other concerns. They do so through “dairy hubs” which are supported by a consortium of 5 organizations and allow for coordination between actors to find shared solutions that benefit multiple parties. However the panel noted that a “champion” or “institutional entrepreneur” must orchestrate innovation platforms and that platforms do not come into existence without significant leadership and support.

The panel also drew on the innovation systems framework put forward in the workshop background paper (see appendix D) to compare the performance of private sector with the public sector in goal-driven innovation systems. The panel found that in many instances the entire innovation system from invention to adaptation and widespread use exists within the single private sector company. In contrast, in most developing countries, there is no single public institution that has a “bird’s eye view” of all stages of the innovation system. In particular, the panel highlighted several things that the private sector does differently to create a well-functioning, end-to-end innovation system within the domain of their organizational control:

1. The private sector understands their market including the varied agro-ecologies their target farmers face.
2. They understand that they are not targeting all farmers and carefully define their strategic niche.
3. They understand both what type and how much of a benefit their product has to offer and understand that not delivering on promised benefits will damage their reputation and lead to long-term failure.
4. They identify farmers’ pathways to market and often help create the market linkages for farmers. They understand that without reliable market opportunities farmers will not adopt new knowledge and technology.
5. And finally they understand that research is not the same as product development. They have very specific and targeted goals in product development.
Despite the benefits of private sector approaches to agriculture innovation systems, the panel noted that when it comes to serving the needs of the most vulnerable farmers, private sector incentives are often not aligned with these goals. Because of this, the public sector and NGOs are essential actors for ensuring the agriculture innovation system serves the needs of vulnerable farmers. The public sector and international civil society (including NARS and CGIAR centers) would benefit from thinking more critically about how to “think like the private sector” while focusing on the needs of vulnerable farmers.

The panel felt that the innovation systems framework would be a constructive tool for public sector and NGOs to “think like the private sector.” By evaluating their activities and strategies from a systems perspective using the framework, public sector actors could ensure a more holistic end-to-end approach to their activities. The panel highlighted the importance of public-private partnerships (PPPs) to fill some of these gaps and build on the strengths of the private sector, while realigning actors’ incentives towards the needs of small farmers. However, the panel also noted that there is no panacea and actors’ incentives do not always align to build successful PPPs. Beyond PPPs, the innovation systems concept highlights the need for public institutions to provide a portfolio of solutions as well as end-to-end strategies for bringing solutions into widespread use. One way of doing this might be by making a special department or individual responsible for understanding the entire system, much like the chief operating officer of a private sector company.

The discussion following the panel explored the theme of incentives between and within organizations in the innovation system. Specifically the discussion turned to how to ensure that public sector, civil society, and international organizations can create an organizational environment that ensures the same holistic perspective that profit-driven private sector actors adopt to survive. Too often the actors in the innovation system most concerned with serving the needs of small and marginal farmers only focus on one stage of the innovation system and miss important linkages that are necessary to achieve their ultimate goals of helping small and marginal farmers. Participants felt that public and civil society actors would benefit from thinking about the services they provide as a demand driven market, even if profit is not the metric used to measure success. Such a demand driven perspective would force public sector actors to adopt the more holistic view of the private sector in meeting their clients’ needs. Of course, demand driven approaches have been tried but widespread adoption of this institutional innovation has not taken place at least partly because of the time and energy required on the part of organizations to pursue this strategy.

Other participants felt that the problem went beyond changing the perspective and incentives of public organizations. Many public organizations understand their market but do not have the capacity and funding to properly serve the needs of vulnerable farmers. Governments and the international community must invest in the goal of serving the needs of small farmers, which is often a costly endeavor. It is seldom aligned with the interests of individual politicians who are easily captured by lobby groups associated with large farmers or other agriculture interest groups.

The importance of traditional knowledge and local innovations, which was discussed at length in panel three, was raised again as a key component that needs to be integrated into a systems perspective of the innovation system. One key to unlocking the potential of traditional farmer knowledge is to better understand and promote traditional farmer-to-farmer communication. Information and communication technology (ICT) is an important new strategy for promoting farmer-to-farming communication.

Participants concluded that promoting effective inclusion of vulnerable farmers in agriculture systems is an important responsibility of public sector actors. The public sector must work to align incentives of actors throughout the agriculture innovation system to serve the needs of small farmers. This is not an easy task. In order to do this the public sector needs to develop a strategy for better
understand the incentives actors face throughout the innovation system and then create institutional structures that can change the rules of the game so that all actors are incentivized to meet small farmers needs. The innovation platform concept discussed by the panel is one way to create a shared understanding of incentives at a local scale. The innovation systems framework can help address this challenge across scales.

Panel 5. What should we do next?

The final panel aimed to shed light on what actors in the innovation system can do to overcome barriers to serving the needs of vulnerable farmers. The panel sought to move beyond the project level to a systems level perspective and included private sector, international civil society and academic perspectives. All identified major barriers as well as opportunities for next steps.

From the perspective of international civil society, the innovation system is functioning well in the invention and selection stages for crop breeding. Despite success in these stages, however, adoption levels among small and marginal farmers are very low. The rate of genetic gain (increase in performance of crops through genetic improvement programs) in Africa is somewhere between 0 and 1% per year. This implies that if the research community wants to make a substantial difference in agriculture productivity over the next 10 years in Africa, something must be done to increase the rate of genetic gain in African agriculture systems. Alternatively, the research community could focus on developing non-seed based approaches to improving agriculture productivity. The barriers to adoption of hybrid crops in Africa are high, but many of these same barriers exist for adoption of other technologies and practices. This is partially because while some crops such as hybrid maize lend themselves to promotion by the private sector, most crops that smallholder farmers grow are almost exclusively developed and promoted by public sector and international civil society organizations. Neither of these actors is particularly good at scaling technologies to widespread use.

The panelist from international civil society implored the academic community to help provide a clearer understanding of the adoption, adaptation, and widespread use stages of the innovation system. Also needed are strategies for overcoming barriers that are generalizable and effective for the public sector and international actors. This begged the question whether donors and international organizations such as the Consultative Group on International Agriculture Research (CGIAR) should get into the business of adaptation and supporting widespread use, taking on the traditional role of many of the ineffective National Agriculture Research Systems (NARS). The panel felt that any move towards work in the stages of adaptation and widespread use would require donors to move away from their project driven funding models, which are not feasible past the demonstration stage of technology development.

The panel underscored the need to think beyond compelling singular technologies to address systems of technologies that provided farmers with opportunities for incremental improvements. These systems need to be supported throughout the value chain, providing farmers access to knowledge and technology and assured markets to capitalize on their investment. Creating a compelling value proposition for farmers is the goal of any end-to-end strategy, but in order to do this you need to understand your customers and properly segment your market to provide solutions that target the needs of very different categories of farmers.

The panel discussed strategies for segmenting the market and targeting the needs of vulnerable farmers. In particular, the panel suggested thinking about three “rural worlds” or socio-economic groups:

1. Large-scale commercial households and enterprises
2. Traditional agriculture households and enterprises
3. Subsistence households and micro-enterprises

These three different types of rural worlds have drastically different needs from the agriculture innovation system. While the first and second categories are focused on investments that allow them to grow their enterprise and eventually make additional investments outside agriculture to achieve even greater returns on investment, the third category is focused on survival. Supporting the third category of farmers to first achieve food security and then helping them to turn their attention to higher value activities that improve their resilience requires evaluating technologies and development strategies using multiple criteria and providing multiple pathways for development to different categories of farmers. But, this is often easier said than done as dominant technological solutions are frequently supported by powerful incumbent interests of farmers in the first and second categories, and reinforced by policy and practice, which is often not well attuned to the needs of the most vulnerable farmers.

The panel discussed the need for public sector and international civil society organizations to prioritize large-scale infrastructure investments. In particular data from Africa suggests that investments in irrigation have a 12% internal rate of return (IRR) on investment. This IRR becomes higher when irrigation schemes are paired with hydro-eclectic projects. The panel noted that despite such strong returns on investment, lending by the World Bank for irrigation is declining. The panel noted that decline in investment is at least partially in reaction to environmental concerns about the impact of large dams. But the panelists felt the pendulum had swung too far and that the agriculture development community must renew its focus on building irrigation infrastructure while looking for alternatives to large dams that have a more limited environmental impact. The overwhelming take-home message of this discussion was that governments and other actors should not continue to neglect large-scale infrastructure investments. These investments generate public goods that benefit both large and small farmers.

The discussion following the panel presentation highlighted the need for public sector and international civil society actors to move beyond project length perspectives to long-term plans for achieving sustained use of knowledge and technology that meets the needs of vulnerable farmers.

Participants discussed the challenges faced by international civil society in making grants beyond the invention, selection and initial adoption stages of the innovation system. In particular, problems in measuring success over the short time horizons required by donors limit the ability of many organizations to invest or make grants in the adaptation and widespread use stages. Moreover, international civil society organizations face challenges finding partners with the capacity to work with them on long-term adoption and widespread use projects. However, with limited capacity of the public sector in many countries, the inability of international organizations to fund such work creates a vacuum of actors in this space.

One example of a country that is overcoming some of these challenges and providing support for adaptation and widespread use is Ethiopia. Ethiopia’s success has been grounded in strategic design of incentives within their public sector agriculture agency, which has been restructured and rebuilt into the Agriculture Transformation Agency (ATA). Through extensive support of private sector consultants and international civil society organizations, the ATA has been able to re-think incentive structures for actors in their agriculture innovation system. It has adopted new approaches to promote private sector investment and PPPs and to ensure that public sector employees are evaluated based on their performance in achieving systems level goals. However mobilizing the resources needed to improve Ethiopia’s agriculture innovation system required significant internal and external investments and many champions.
Finally, the panel returned to the issue of scaling pockets of prosperity that was brought up in the second panel. It called for an agricultural research agenda framed tightly around expanding these pockets of prosperity into widespread success. The final panel ended with a set of questions all actors in the agriculture innovation system should ask themselves:

1. What is my strategic niche?
2. What are other actors in the innovation system doing and how do their activities complete, compete, or impede my goals?
3. What should I be asking other organizations to do in order to build on each other’s strengths to improve the innovation system to meet the needs of vulnerable farmers?

**Workshop Synthesis**

In summary, the goal of the workshop was to explore key challenges in the innovation system for drought and water scarcity adaption technologies intended to meet the needs of small and marginal farmers. The workshop was structured around five panels which led the discussion from description of major challenges faced by vulnerable farmers in adapting to drought and water scarcity, to description of successes and failures by the agriculture innovation system in meeting those challenges, to analytic evaluation into causes of barriers and bottlenecks in the innovation system, to better serving the needs of small and marginal farmers. On the second day, the final two panels discussed systems level approaches to evaluating barriers and designing interventions to better orient the innovation system so that it addresses the needs of vulnerable farmers and to providing incentives for actors and organizations in the innovation system to make the necessary changes for meet these goals. Below are the key findings of each of the five panels:

**Panel 1: What are the major challenges?**

First, the most critical challenge in the agriculture innovation system for drought adaptation technologies is getting existing technologies into widespread adoption and use.

Second, understanding the many types of drought and water scarcity farmers face and will face under climate change is a major challenge in developing new technologies to meet farmers’ needs.

**Panel 2: How well are we doing?**

There are pockets of prosperity where existing technology has helped farmers to overcome drought and water scarcity.

But, scaling pockets of prosperity beyond isolated regions in order meet the needs of the majority of small and marginal farmers remains a major unmet challenge.

**Panel 3: Why are we not doing better?**

First, the research and development community consistently fails to focus on the specific and context-dependent risks vulnerable farmers face when adopting new knowledge and technology.

Second, failure of public and civil society sector actors to view their activities holistically within the context of the agriculture innovation system leads to invisible bottlenecks that no actor has the ability to overcome on their own.
Panel 4: How could we do better?

First, public sector and civil society actors should strive to create demand-driven innovation systems to meet the needs of the most vulnerable farmers. Learning from the approach of the private sector and using an innovation systems perspective are two strategies for achieving this goal.

Second, the capacity of farmers to make demands on the innovation system to meet their needs must be enhanced through improved primary education and capacity building and a greater focus on farmer-generated knowledge and technologies.

Panel 5: What should we do next?

First, we need to focus on portfolios of technologies and not one-off investments. Drought and water scarcity are landscape level challenges and should be addressed as such though a systems based approach to innovation.

Second, technologies targeted at small and marginal farmers should be indexed in terms of risk profiles along a range of criteria that take into account the characteristics of the technology itself as well as the social-environmental system in which the technology will be used.

Finally, the public sector should work to strategically align the incentives of public private and civil society actors to meet small farmer needs in the context of drought and water scarcity.
Appendix A: Workshop Participants

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Anil Verma
Executive Director, PRAN (Preservation and Proliferation of Rural Resources in Nature), Gaya
Appendix B: Workshop Agenda

Wednesday September 10th, 2014

3:00pm: Tour of glass flower exhibit at Harvard’s Museum of Natural History.

6:00-8:00pm: Dinner at Harvard University Center for the Environment.

Thursday September 11th

8:30-8:45am: Arrive & Coffee: Hoffman Labs 4th Floor Faculty Conference Room

8:45-9:00am: Welcome Remarks

9:00-10:45am:
Panel I: What are the major challenges?

10:45—11:15am: Coffee Break

11:15-1:00pm:
Panel II: How well are we doing?

1:00-2:30pm: Lunch: Daly Seminar Room; Harvard University Museum 105

2:30-4:15pm:
Panel III: Why are we not doing better?

6:00-8:30pm: Working Dinner at the Harvard Faculty Club

Friday September 12th

8:30-9:00am: Arrive & Coffee: Hoffman Labs 4th Floor Faculty Conference Room

9:00-10:45am:
Panel IV: How could we do better?

10:45-11:15am: Coffee Break & Workshop Photograph

11:15-1:00pm:
Panel V: What should we do next?

1:00-2:30pm: Lunch: Daly Seminar Room; Harvard University Museum 105
Appendix C: Background Materials Submitted in Advance by Conference Participants

Workshop participants were asked to submit one paper or report that most closely connected their interests with the theme of the workshop. Many of the papers submitted were working papers or unpublished notes. For readers who want to access one of the unpublished documents, please contact the corresponding author and she will connect you with the appropriate author to request access. Papers are in alphabetical order by last name of submitting participant.


Soman, Dr. P. “Adapting micro irrigation technology for small farm in India.” Notes submitted for workshop.


Sumberg, James, John Thompson, and Philip Woodhouse. (June 2012) “Why agronomy in the developing world has become contentious.” Agriculture and Human Values. DOI 1007/s10460-012-9376-8.10.


Valentim, Judson, and Rachael D. Garrett. (2014). “Promoting the well-being of small farmers through low carbon agriculture and forestry production systems in the Brazilian Amazon biome.”

Appendix D: Conceptual Framework for Studying Goal Oriented Innovation System

Figure 1: Diaz Anandon et al., 2014