The Economist Intelligence Unit

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Global food security index 2015

SPECIAL REPORT

The role of innovation in meeting food security challenges

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Executive summary

Global food production must ramp up in the face of enormous challenges. We are all familiar with many of the key metrics surrounding the central food security challenge: By the year 2050, the earth's population is expected to soar from the current 7bn about 9.6bn. It is estimated that in the next 40 to 50 years, we will need to produce as much food as was necessary in the previous 10,000.

This requires a dramatic increase in agricultural production, which must be achieved against a backdrop of issues such as climate change (and the attendant ills of extreme weather, flooding and droughts), water and soil depletion and degradation, and possible yield plateaus in key production regions for wheat and rice. The need to intensify production on existing lands rather than relying too heavily on new ones—which would require deforestation or the clearing of savannahs—will also require new technologies all along the agricultural chain, to boost production and replenish overworked farmland.

Innovations are underway on every major front... Human ingenuity and innovation have always been at the core of meeting challenges, and in doing more with less. The situation here is no different—and this report covers how agricultural technology is moving ahead on a range of fronts to address the world's growing food security issues. These include the development of software to lessen water usage, digital soil maps and testing kits, advanced farm management techniques, improved inputs, and new seed varietals to produce crops that are higher-yielding, more stress- and drought-tolerant, and fungal-resistant, as well as less reliant on dangerous pesticides or nitrogen fertilisers, the latter of which are a major source of greenhouse gases.

...Often driven by public and private partnerships. Many governments are investing heavily in biotechnology research such as genome editing, with the goal of producing stronger, more resilient crops and commercialising their discoveries. Facing critical environmental issues and population pressures, China has emerged as the greatest source of public investment in research, not only in biotechnology but also in soil protection/remediation and water conservation. The state is also encouraging private companies to test their technologies on designated lands, with its scientists monitoring the results. The US is another major force; for example, the Department of Agriculture made a major breakthrough in the sequencing of the wheat genome, and research on similar fronts is underway.

Some governments are also reconsidering their restrictions on genetically modified crops, as they seek to boost production and increase the capacity of their seed industries to develop new and better varieties.

Government support often spurs the involvement of other players, especially those in the private sector, which is more risk tolerant and can often push projects to the next level. Public-private partnerships are evolving across the globe, on projects to improve farm management techniques, reduce water use and increase retention, predict and adjust to changing weather conditions, and strengthen and replenish soils. New software is tying networks of scientists together to tackle modeling and analysis, and connecting companies with policymakers and researchers. Within the private sector itself, investment in agricultural technology is increasing so rapidly that many funds now focus specifically on the sector.

Meanwhile on the ground, many NGOs are working with farmers to develop innovative, sustainable methods of production, while others are revolutionising the credit industry to make funding more accessible to smaller players.

Smallholders play a critical role in meeting food demands. An estimated 2.5bn people live in about 500m small farm households—and increasing their levels of production is crucial. This requires greater access to high-quality agricultural inputs as well as to finance and credit. Private firms and NGOs are responding with creative financing tools, a range of new technologies to help them farm more abundantly, sustainably and efficiently, and better seeds, fertilisers and soil management tools.

Urban agriculture holds potential—and governments are eager to maximise it. Urban agriculture is attracting increased attention as a means of improving food security and dietary diversification for the urban poor. By 2050, an estimated 66% of the world's population will be urban, and the largest urban population increases will be seen in cities in Asia and Africa. City and national governments will need to look to a range of solutions to meet the pressures put on urban food systems, and their ability to provide fresh, nutritious food. While the scalability and effectiveness of current urban agriculture models remains to be seen, and data collection must be improved, governments are already working with non-profits to help not only with the production and distribution of food, but also with job training and nutritional education.

This report provides examples of recent projects that are already having an impact on urban food access in cities around the world – ranging from New York, where NGOs are partnering with federal agricultural agencies on local farm and nutrition programmes, to Beijing, where concerns about food safety and quality are sparking government interest in urban organic farming projects. ■

Introduction

According to the United Nations (UN), the global population is expected to jump from slightly over 7bn to around 9.6bn by 2050, with most of that increase occurring in the developing world.[1] As population and incomes increase in those regions, it is estimated that food production will have to grow by 70% in order to meet demand.[2] Addressing this challenge depends on a vast array of factors, but this report focuses on the role innovation must play if production is to keep pace with population growth and food security is to be achieved.

Investments in agricultural research and development typically produce significant returns—but over the long term. It often takes two to three decades from the start of basic research for major technologies to become widely adopted and unleash their full benefits.[3] Consequently, the research and investment decisions made over the next decade or so will largely determine the ability of global agricultural systems to meet mid-century demand for food. This report aims to provide a snapshot of the innovative efforts to address this massive challenge, including cutting-edge developments in areas such as precision agriculture and biotechnology; business models designed to bring these advances directly to those who need them; and new ways to help smallholder farmers increase their production, which will be crucial to meeting demand. We'll close with a look at the potential for urban agriculture to improve food security for low-income residents in cities. ■

1 U.N. World Population Prospects: 2012 Revision.

2 FAO High-Level Expert Forum, "Global Agriculture Toward 2050", October 2009.

3 Philip G Pardey, "Agricultural Innovation: the United States in a Changing Global Reality", *Global Agricultural Development Initiative*, April 2013.

1. Overview

Innovation is crucial to meeting key challenges

Dramatically increasing the global food supply is a daunting enough challenge on its own, but several significant headwinds make the task even more complicated, underscoring the need for innovative solutions.

Climate Change: While a rapid rise in agricultural production is required to meet growing demand, other important factors—chiefly environmental issues—also come into play. Climate change has already begun to affect crop yields and threatens to cause greater damage as the century progresses.[4] Increased incidences of extreme weather associated with climate change—such as drought, consecutive days of extreme heat, and flooding—are issues that might be even harder to solve.[5] And the effects on developing countries will be even more severe.

Climate change is also restricting the means by which production can be ramped up. Because of the need to drastically reduce anthropogenic greenhouse gas emissions in order to avert the worst consequences of climate change, production gains must come largely from intensification of existing lands rather than expansion into new ones, which usually results in the increased emission of greenhouse gases as a result of deforestation or the clearing of savannah.[6] This necessitates innovation along almost the entire agricultural value chain.

Soil Quality: The process of intensification is exacerbated by soil quality issues in critical production and consumption regions. In China, which relies on around 7% of global arable land to feed 20% of the world's population, the Ministry of Land Resources recently reported that 19% of such land is polluted, more than 40% is degraded due to "soil and water loss, soil impoverishment and salinisation", and over half is severely deficient in total organic matter. High concentrations of heavy metals that have leached out of nearby mines and industrial sites are the most significant culprit, but excessive dependence on chemical fertilisers has also played a major role.[7] In most of Sub-Saharan Africa (SSA), the opposite problem has long limited yield growth: lack of fertiliser use is believed to be the principle reason African yields did not improve during the Green Revolution.[8]

Water Depletion: Climate change is already affecting water availability in numerous ways, as precipitation patterns change or become more intense, major storm tracks such as El Nino shift, and extreme weather events become common. Areas that are currently subject to dry conditions will get drier, and those with already-high levels of rainfall will get wetter.[9]

Underground water pollution is also a significant issue, notably in China.[10] In addition, the unsustainable use of critical aquifers in Asia and North America has resulted in extractions

4 Senthold Asseng et al., "Rising temperatures reduce global wheat production", *Nature Climate Change*, December 2014.

5 Wolfram Schlenker, "Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change". Proceedings of the National Academy of Sciences of the U.S.A., 2009.

6 Senthold Asseng et al., Ibid.

7 Ying Zhang, "Soil Quality in China—Policy Implications", *Europe China Research and Advice Network (ECRAN)*, August 2014.

8 Generose Nziguheba et al., "The African Green Revolution: Results from the Millennium Villages Project". *Advances in Agronomy*, Vol. 109, 2010.

9 Stephanie Paige Ogburn and Climatewire, "Climate change is altering rainfall patterns worldwide", November 12th 2013.

10 U.N. Water, "Water for a Sustainable World: the United Nations Water Development Report 2015", 2015.

significantly above the natural ability of the aquifers—which serve 1.7 billion people—to replenish themselves.[11]

Yield Plateaus: It is possible that key production regions for wheat and rice—northern Europe and China, respectively—have reached yield plateaus, which will require investments in new techniques to either increase yields in those regions or improve yields in regions that have more potential.[12]

11 Tom Gleeson et al., "Water Balance of Global Aquifers Revealed by Groundwater Footprint", *Nature*, August 8th 2012.

12 Patricio Grassini et al., "Distinguishing between yield advances and yield plateaus in historical crop production trends", *Nature Communications*, December 2013.

2. Every Sector Is Heeding the Call for Innovation

Governments, international institutions, NGOs, private companies and universities are all investing significant sums to develop innovative solutions to these problems. Government support, in the form of basic research funding and other incentives, frequently acts as an important catalyst for innovation in the private sector. But impact lenders, foundations and NGOs are also playing an ever-larger role, especially in efforts to help small farmers increase their productivity and in urban agriculture start-ups—thanks to innovative business models and a risk tolerance that governments generally cannot afford. Where these models have been successful, governments have often stepped in to scale up the projects. Several companies and institutions are also forging connections between sustainable agricultural technology providers and policymakers.

Some key examples of the global response:

Smart agriculture in China: As a result of population pressures and daunting environmental challenges, China has emerged as the main testing ground and greatest source of public investment for a variety of new agricultural technologies. For example, under its Soil Pollution Action Plan, the central government is funding six protection and remediation pilot projects, with each receiving $1-1.5bn RMB (US$160-240mn), and there are expectations that it will eventually invest a much larger sum to roll out the most successful soil remediation policies and technologies.[13] And local governments have designated significant amounts of land as "demonstration bases", where private companies are invited to test new technologies or practices; the results of the trials are then reviewed by state officials and academics.[14]

Beijing-based Smart Agriculture Analytics (SAA) has positioned itself as the link between the country's agricultural sector and small to mid-sized companies that own best-in-class technologies. Launched in 2012, SAA offers online subscriptions to market research in the form of data feeds tailored to provide subscribers with information on potential market opportunities for their products, as well as policy shifts that often create such opportunities. Subscribers range from major manufacturers of poultry and swine production equipment, to a producer of fertilisers intended to improve soil health by increasing soil microbial activity, to manufacturers of precision agricultural equipment, such as Raven Industries. Smart Agriculture Analytics has also attracted interest from investors, and counts the International Finance Corporation (IFC) among its subscribers.[15]

Connecting global knowledge networks to improve policymaking. The Agricultural Model Intercomparison and Improvement Project (AgMIP) also coordinates global actors in the agricultural value chain, connecting policymakers with the best scientific work on how climate change and policy decisions could affect their agricultural systems. The project is supported by entities such as UKAID and the USDA, with infrastructure provided by NASA, Columbia University's Earth Institute, the University of Florida and Oregon State University. AgMIP's team of climate, crop and economic experts have created an open-source software platform with standardised data that accommodates intercomparable models of future climate scenarios, to predict the effects that each scenario would have on crop yields and prices. Its small core team leverages a vast global network of experts, establishing in-country partnerships with scientists, researchers and policymakers to guarantee that on-the-ground knowledge informs modeling, analysis and policy suggestions.

AgMIP works with policymakers in developing countries to estimate the effects of their decisions on their agricultural systems. Governments can ask its team to model, for example, the expected benefits that fertiliser subsidies or public investments in irrigation systems would have under a variety of climate and economic scenarios in the short and the long term; by partnering with in-country experts, the team can also model the myriad effects such policies could have on everyone from smallholder farmers to private companies throughout the value chain. AgMIP is also assisting with policy recommendations for longer-term climatic changes: its crop team is matching up seeds with genetic traits that would be desirable under different scenarios with regions that could benefit from them. The economic team is exploring policy options to help increase off-farm income for smallholders in regions where climate change is expected to have especially detrimental effects on farm income. Its pest and disease team is developing responses to the rapidly changing nature of these outbreaks.[16]

Emerging research and technology transfer is improving inputs. Research and commercialisation of genetically modified plants is expanding beyond varieties that resist pests, weeds and diseases, into those that could also help reduce greenhouse gas emissions by decreasing fertiliser use or allowing crops to better withstand the stress of extreme weather events such as flooding and drought. With the help of funding from the USDA and the National Science Foundation (NSF), Dr. Stephen Moose, a professor of plant genomics at the University of Illinois, has been leading research into how corn uses nitrogen, focusing on the genes that control

13 Angel Hsu, "China's Soil Pollution Crisis Still Buried in Mystery", *Environmental Performance Index*, August 6th 2014.

14 Interview with Manuela Zoninsein, CEO and founder of Smart Agricultural Analytics.

15 Ibid

16 Interview with Dr. Alexander Ruane, researcher at the NASA-Goddard Institute for Space Studies and leader of the climate team for AgMIP.

when the plant uses, versus storing, the element.

Because corn evolved with extremely limited access to usable nitrogen, it employs it conservatively, often storing rather than spending it to create more seeds. Understanding exactly when corn needs significant amounts of nitrogen to maximise yields could allow researchers to rewire corn, via gene editing, so it uses nitrogen more efficiently, which would allow for reduced fertiliser levels.[17] Because the principal raw material in nitrogen-based fertilisers is natural gas, this could lower the sector's GHG emissions and also lessen water eutrophication, which occurs when water receives an excess of nutrients that leads to algae blooms. When the algae die and decompose, "high levels of organic matter and decomposing organisms deplete the water of available oxygen, causing the death of other organisms, such as fish." Eutrophication is often caused by the surface runoff of nitrogen-based fertilisers.[18]

The benefits of such a corn varietal could also be significant for small farmers, who generally have limited access to chemical fertilisers, by allowing them to maximise the effectiveness of their inputs. Policymakers might also be able to improve the efficacy of their fertiliser subsidy programmes. Some obstacles remain, however; for example, the balance between the photosynthesis that occurs during the day and the nitrogen assimilation that happens primarily at night is different for corn grown in the long summer days of the midwestern United States from that of corn grown in the tropics, which has consistent 12-hour days. Also, many African countries allow only corn varietals that were developed by conventional breeding techniques or marker-assisted selection. But such problems are not insurmountable, and Dr. Moose points to the NSF's Basic Research to Enable Agricultural Development (BREAD) grants, which focus on research that could assist smallholders, as a way to finance the knowledge transfer.[19]

17 Interview with Dr. Stephen Moose, Professor of Maize Genomics at the University of Illinois' Department of Crop Sciences.

18 United States Geological Survey, "Environmental Health—Toxic Substances", http://toxics.usgs.gov/definitions/eutrophication.html

19 Interview with Dr. Stephen Moose.

3. Smallholder Farmers: Crucial to Food Security

One size does not fit all. According to a 2013 report on smallholder farming by the Consultative Group to Assist the Poor (CGAP), an estimated 2.5bn people reside in about 500m small farmer households in the developing world.[20] Although there is no one definition for a such a farm, it generally applies to those where production "occurs on less than two hectares of land, is characterised by low yields, low quality, poor linkages and little access to finance".[21]

Small farmers must raise their yields...
Improving smallholder production is essential to raising global agricultural yields, but even more important for enhancing food security, as these farmers often are among the world's poorest and it is estimated that about 60% of them farm for subsistence.[22] Their ability to increase production will largely depend on improving their access to better inputs, particularly fertilisers and seeds, as well as training to develop more efficient practices. In the context of the Maputo Declaration, many African governments have begun subsidising fertilizer and seed costs and investing heavily in improved extension services and agricultural

20 Robert Peck et al., "Segmentation of Smallholder Households: Meeting the Range of Financial Needs in Agricultural Families", CGAP Focus Note: No 85, April 2013.

21 Tom Carroll et al., "Catalyzing Smallholder Agricultural Finance", Dalberg Global Development Advisers, 2012.

22 Robert Peck, Ibid.

infrastructure. Private companies and NGOs have also entered this space, often making use of digital technologies, while policymakers are helping to scale up the number of farmers who can access them.

...Which means raising cash. Techniques pioneered by impact lenders such as Root Capital and Oikos have opened up short-term financing to smallholders who generally belong to cooperatives and grow cash crops for export, for which there are large, consistent buyers whose contracts can serve as collateral. Their work eventually opened the door to local commercial lenders and policy banks, which have brought considerably more capital to the sector. While the model represents a major advance for millions of smallholders, those who qualify for such loans represent only about 10% of the total—mostly coffee bean farmers in Latin America, where there are long-standing traditions of cooperatives.[23] As of 2013, the "total amount of debt financing supplied by local banks to smallholder farmers in the developing world [was] approximately $9 billion", which meets less than 3% of the estimated total smallholder financing demand excluding China.[24]

Reaching the remainder has been difficult because they are not generally organised and do not sell cash crops for export. Even smallholders who can access short-term financing are usually unable to obtain longer-term loans, which are essential for investments such as the purchase of new coffee plants, which tend to have a productive lifespans of about 20 years.[25] Serving the remaining small farmers represents a new frontier for impact lenders and will require a variety of approaches, such as warehouse receipt financing, whereby farmers can take out loans on a percentage of their crops' value until they sell them, allowing them to hold off on selling their crops at harvest time when prices are most depressed. The IFC has been promoting such lending by offering partial guarantees to banks. It has also been partnering with Rabobank and several African governments to coordinate the expansion of warehouses as well as their adoption of digital platforms, which provide greater transparency about crops and prices. If commercial banks are connected to the platforms, transactions can occur instantly.

Potential lenders find it difficult to evaluate the credit risk of most smallholders, and in many low-income countries, credit bureaus that might provide these data do not exist. In response to this void, some companies and impact lenders, such as First Access and Cignifi, are using the digital footprints of mobile phone customers to generate alternative credit scores. According to the Partnership for Financial Inclusion, "When combined with information gathered directly from the borrower such as income and marital status, data analytics companies gauge the creditworthiness of potential clients and estimate loan amounts that can be extended to them."[26] The Initiative for Smallholder Finance (ISF) is also working to improve the availability of credit information by coordinating alliances among impact lenders to improve the aggregation and sharing of data.[27]

Insufficient capital remains the most significant challenge to scaling up smallholder lending—but good business practices and knowledge of the sector are also essential. Dan Zook, a portfolio manager at the ISF, notes that considerable sums are flowing into the impact lending space from projects such as the MasterCard Foundation's Fund for Rural Prosperity, Danone and Mars' Livelihood Fund for Family Planning and USAID's Feed the Future Initiative. The ISF is now turning its attention toward building deal pipelines. Leveraging its knowledge of the market and its relationship with lenders, it plans to act as a pre-deal facilitator, identifying opportunities that currently lack an "anchor actor" who could bring

23 Tom Carroll, Ibid.

24 Dan Zook et al., "Local Bank Financing for Smallholder Farmers: a $9 Billion Drop in the Ocean", Initiative for Smallholder Financing, *Briefing 01*, October 2013, 02.

25 Tom Carroll, Ibid.

26 Marcia Parada et al., "In the Fast Lane: Innovations in Digital Finance", Special Report for the Partnership for Financial Inclusion, May 2014, 13.

27 Interview with Dan Zooks of Dalberg Global Development Advisers.

In focus:
Helping Small Farmers to Access Technology

According to the International Food Policy Research Institute (IFPRI,) the Indian Government views public-sector extension services as the vehicle for "bridg[ing] the yield gap between agricultural research outputs and farmer fields"—but surveys have shown that such services account for only a small percentage of the information accessed by farmers.[1]

One solution is to bring technology directly to the fields. Digital Green, an India-based NGO that uses tech to improve agriculture and health conditions in rural communities across South Asia and Sub-Saharan Africa, has been helping small farmers—many of whom are women—access technology to share agricultural techniques that can help them produce crops more abundantly, efficiently and sustainably. The programme, which operates under the auspices of the Ministry of Rural Development's (MRD) flagship National Rural Livelihood Mission (NRLM), reaches remote small farmers in a cost-effective manner while reducing the amount spent on extension services.

Digital Green teaches farmers to produce training videos to share with their peers. The group distributes pocket digital video cameras and tripods, and trains farmers in storyboarding, shooting, editing, screening and even acting in and directing the videos, which demonstrate innovative agricultural techniques that relate to local crop cycles. Because electricity is often sketchy, the farmers screen the videos on battery-powered projectors, and follow up with question-and-answer sessions. They then keep track of how widely the new practices are adopted, to gauge the success of the videos and improve them if necessary. This has also allowed the NGO to determine that, on a cost-per-adoption basis, its approach is "ten times more effective per dollar spent than a classical extension system".[2]

The NRLM has organised these rural communities of farmers into what it terms "self-help groups" that meet about once every two weeks to work together on knowledge-sharing projects. The original groups focused on microcredit, which also comes into play when discussing the potential value of the new farming techniques they learn about in the videos.

So far, the programme has reached 4,000 villages (400,000 farmers), with plans to connect to a total of 10,000 villages (1m farmers) over the next two years. Digital Green also works in Afghanistan, Ghana, Tanzania and Mozambique and has now expanded to Ethiopia, where it works with the Ministry of Agriculture, aiming to reach 1m small farmers within three years. In studies conducted by the NGO, its training methods were shown to significantly increase the adoption of certain agricultural practices more cost-effectively than traditional extension programmes.

Although it also partners with other NGO's and private agri-buyers, government cooperation and assistance have been instrumental in scaling Digital Green's efforts. In India, the MRD covers the capital equipment and operational expenses for the programme while village-level extension agents help present the videos. This approach highlights the many benefits of public-private partnerships, as Digital Green and the Indian government team up to employ a simple, inexpensive technology to disseminate crucial information quickly and effectively to a massive number of farmers.[3]

1 Claire J Glendenning et al., "The Relevance of Content in ICT Initiatives in Indian Agriculture", IFPRI Discussion Paper 01180: April 2012.

2 Rikin Gandhi, "Digital Green: Participatory Video and Mediated Instruction for Agricultural Extension". *Information Technologies & International Development*, Spring 2009.

3 Interview with Rikin Gandhi, Founder and CEO of Digital Green

the necessary parties together. The group would perform market research, help design business models and determine how best to align the interests of the stakeholders for a given project.[28]

Improving soils for smallholders. A range of new technologies and initiatives are tackling the challenge of soil management, with small farmers in mind. With funding from the Gates Foundation, the Earth Institute at Columbia University—in collaboration with the World-Agroforestry Center, the International Soil Research and Information Centre of the Netherlands and national governments—is working on the Africa Soil Information Service project. This project looks to use both legacy soil data and modern spectrometers to develop digital soil maps with improved soil profiles. The project will provide

28 Ibid.

information on a number of properties—including clay content, organic carbon and pH levels—which in turn allow for "inferred predictions about more difficult to measure soil properties, available soil water storage, carbon density and phosphorous fixation". The maps will also include detailed information on socioeconomic conditions, and should assist policymakers in crafting more effective irrigation, fertilizer and land use initiatives.[29]

The Earth Institute has also produced an onsite kit to measure soil quality at a more micro level. Its SoilDoc kits are essentially mobile wet chemistry labs that extension agents or private-sector companies can use to run on-site soil tests to determine available macronutrients—such as nitrogen, phosphorous, sulfur and potassium, which are essential for plant growth—as well as soil properties. The kits represent a significant upgrade from past methods, as they require no distilled water and no electricity which has been a major obstacle to on-site soil tests in rural areas. In addition, the test can be sent to the lab via android tablet and results come back in a day or two. Results can then be sent, along with a set of soil recommendations, to farmers via text messages.[30] The kits complement the Soil Information Service project, which does not measure nutrient availability, and the results can be uploaded to digital maps via a crowdsourcing tool.

Eventually, algorithms will convert the test results into an immediate set of soil management suggestions, similar to services offered in developed agricultural markets. The project is being tested in Nigeria and Tanzania, and efforts are underway to alert the private sector to opportunities here. With more detailed knowledge of soil nutrient levels, fertiliser companies should be able to improve their products, and private companies might develop entities—perhaps in the form of public-private partnerships—to set up the same kind of tests at affordable prices, thus allowing the model to scale up.[31] India already has a similar project: in 2013, the country launched mobile soil labs that can test for macro- and micronutrient availability in a day;[32] more recently, it began issuing Soil Health Cards to advise farmers about the best inputs based on their soil profiles.[33]

International partnerships to improve seed varietals. Improved seed varieties are an essential component of protecting yields on smallholder farms from crop diseases, pests and weeds, as well as from extreme weather events such as drought and flooding. With the exception of a few large middle-income countries, private-sector investment in agricultural R&D is largely absent in the developing world, and public-sector funding, while improving in many countries, remains too low to address the challenges. The flow of aid is still significantly below desired levels, but the Gates Foundation and USAID are funding projects to develop seed varieties that will benefit farmers in developing countries while also improving capacity building at national R&D agencies.

With funding from UKAID and the Gates Foundation, Cornell University runs the Durable Rust Resistance in Wheat project to track the spread of wheat rust, a pathogen that has historically caused significant yield losses, and develop new varieties that resist the pathogen and endure high-stress weather events. Toward the end of the millennium, outbreaks began again in East Africa, and it is estimated that about two-thirds of global wheat production, including more than 80% of production in Sub-Saharan Africa (SSA), is climatically vulnerable to wheat rust. Cornell is coordinating research with 20 institutions around the globe.[34]

The Water Efficient Maize for Africa (WEMA) project is developing new varieties of maize with better tolerance for drought. The project is a public-private partnership, with the Gates

29 Pedro Sanchez et al., "Digital Soil Map of the World", *Science*, August 7th 2009.

30 Cheryl Palm et al., "Evaluating the effect of site-specific soil information on farmer input choices and the relationship between poverty and soil quality", A Proposal to the BASIS CRSP, January 2014.

31 Interview with Dr. Pedro Sanchez of the Earth Institute.

32 *The Times of India*, "Mobile Soil-Testing Lab to Help Farmers", June 1st 2013.

33 Harish Damodaran, "Explained: soil on my fingertips", *The Indian Express*, February 22nd, 2015.

34 Cornell University, "Borlaug Global Rust Initiative", 2013.

In focus:

Improving Access to Finance for the Poorest and Remotest Smallholders

Research on smallholder finance has shown that reaching farmers in value chains with few points of aggregation—such as warehouses, agro input dealers or cooperatives—presents the greatest challenge for the sector. Operating in its base in Kenya as well as in Tanzania, Rwanda and Burundi, One Acre Fund is an agriculture nonprofit that makes direct loans, in the form of farm inputs, to some 280,000 smallholders. The loan packages, disbursed by its field agents a couple of months before planting season, include seed, fertiliser, training and limited crop insurance. Farmers must pay back 10% of the loan before receiving inputs, but the rest can be paid any time before the repayment deadline a few weeks after harvest. This frees up income for other expenses, such as school fees for their children. According to its 2014 Annual Report, farmers who enroll with One Acre Fund increase their incomes on average by over 50 percent on every planted acre[1]. Access to capital, however, remains the major challenge. While the organization has a high rate of farmer loan repayment (99 percent), which covered 74% of its field operations costs in 2014, expansion to new geographic areas requires additional funding.[2] This could reflect the difficulty of trying to reach the poorest smallholder farmers. One Acre Fund would like to see an increase in available working capital at concessional rates to help incentivize microfinance institutions to serve this market.

1 One Acre Fund, Annual Report, 2014.

2 Interview with Stephanie Hanson, Senior Vice President, Policy & Partnerships for the One Acre Fund.

Foundation and USAID working with Monsanto, which supplied the genetic material. Coordinating with national agricultural research systems in five African countries, the project is developing drought-tolerant corn varietals using three different techniques—conventional breeding, marker-assisted selection and genetic modification—that fit the variety of regulatory approaches. In trials, the new seeds, set to be released in 2017, have yielded 20-30% higher production levels than those of conventional hybrids.[35]

Genetically modified (GM) seeds: For the most part, these international partnerships are improving seed varieties via conventional breeding techniques, but some projects are developing GM seeds. One example is a Bt eggplant that is suitable for Bangladesh, which was developed by an Indian seed company and scientists from Cornell University, with funding from USAID. The eggplant has resistance to pests that often cause yields to drop by as much as 50%, forcing farmers to regularly apply high levels of dangerous pesticides.[36] Its commercialisation in Bangladesh was approved in early 2015, but it continues to be prohibited in the Philippines and India, which, as a top global producer of eggplant, could reap important economic, health and environmental benefits from its approval.[37] Researchers in Uganda are currently in field trials for a transgenic banana that has built-in resistance to a bacterial disease that, by causing discoloration and early ripening, costs the Great Lakes region around $500m annually. However, even if trials prove to be successful, farmers there will not benefit, as planting the crop would be prohibited in Uganda and Kenya.[38]

Many scientists who argue in favor of more open regulatory frameworks for GM crops emphasise that developing countries, and particularly smallholder farmers who have limited access to agricultural inputs, are hurt the most by bans on such crops. Country restrictions on the planting of GM crops are based principally on the Cartagena Protocol on Biosafety under the UN Convention on Biological Diversity, which allows governments to "restrict

35 Calestuous Juma, "Taking Root: Global Trends in Agricultural Biotechnology", *Belfer Center for Science and International Affairs*, January 2015, 12.

36 USAID, "Pest Resistant Eggplant: India, Bangladesh, Philippines". *Fact Sheet*.

37 Interview with Dr. Peter Davies, International Professor of Plant Biology at Cornell University.

38 Calestuous Juma, "Taking Root: Global Trends in Agricultural Biotechnology", *Belfer Center for Science and International Affairs*, January 2015.

the release of products into the environment or their consumption even if there is no scientific evidence that they are harmful".[39] Opponents of the crops have cited the potential development of super weeds, concerns over food sovereignty if companies are allowed to patent seeds, and possible health effects to humans. These concerns, however, have yet to be confirmed by evidence.[40] A report commissioned by the European Commission in 2010 "summarised the results of 130 research projects involving more than 500 independent research groups and concluded that biotechnology is not per se riskier than conventional plant breeding technologies.[41]

Genetically modified crops have also brought significant benefits to farmers in the developing world. India's adoption of Bt cotton in 2002 has allowed it to jump from being a net importer of the fibre to the world's second-largest exporter, while also drastically reducing the application of dangerous pesticides and raising economic returns for farmers.[42] Similar results have been found in China, where it is estimated that Bt cotton accounts for half of the crop planted.[43] [44]

There are indications that a number of developing countries that currently limit or prohibit the planting of GM crops are looking to reverse course and increase the capacity of their seed industries to develop and commercialise GM seeds. Since 2002, Bt cotton has been the only GM crop allowed to be grown in India,[45] but Prime Minister Narendra Modi recently approved field tests for transgenic crops, which had been banned since 2010.[46]

The regulatory environment in China is more complicated: the country is the sixth-largest producer of GM crops in the world by area, but currently allows the planting of only six such crops.[47] The central government invested $3.5bn in basic research for biotechnology in 2008, but the current administration has sent mixed signals regarding the commercialisation of GM crops.[48] At the same time, past public investments in biotechnology are beginning to produce results. Using genome editing, Chinese researchers recently bred a variety of wheat that is resistant to powdery mildew, a fungal pathogen. The regulatory decision on its commercialisation is pending.[49]

39 Calestous Juma, *New Harvest*, Oxford University Press: 2011, 39.

40 Pamela Ronald, "Lab to Farm: Applying Research on Plant Genetics and Genomics to Crop Improvement", *PLOS Biology*, June 2014.

41 Torbjörn Fagerström et al., "Stop Worrying, Start Growing", EMBO Reports, Rep. 2012 Jun; 13(6).

42 Calestuous Juma, "Taking Root: Global Trends in Agricultural Biotechnology", *Belfer Center for Science and International Affairs*, January 2015.

43 Andrew Anderson-Sprecher et al., "People's Republic of China: Agricultural Biotechnology Annual", USDA GAIN Report Number: 14032, December 31st 2014.

44 Pamela Ronald, Ibid.

45 USDA Foreign Agricultural Service, *India: Agricultural Biotechnology Annual*, 2014.

46 Krishna N Das et al, "Modi Bets on GM crops for India's Second Green Revolution", *Reuters*, February 21st 2015.

47 USDA Foreign Agricultural Service, *China: Agricultural Biotechnology Annual, 2014*.

48 Andrew Anderson-Sprecher et al., Ibid.

49 David Talbot, "Chinese Researchers Stop Wheat Disease with Gene Editing", MIT Technological Review, July 21st 2014.

4. Urban Agriculture

There has been considerable interest in urban agriculture as a tool for improving food security for low-income city residents; the topic has become even more relevant in light of increasing urbanisation in the developing world. Questions about scalability persist, and policy guidance is still hindered by a lack of data, but the sector is gaining acceptance in the developed world, including among policymakers.

In the United States, the USDA's National Institute of Food and Agriculture (NIFA) supports urban agriculture projects as a tool in its multi-pronged approach to addressing food insecurity and nutrition in low-income areas, particularly for residents of food deserts where access to affordable and nutritious food is extremely limited. The institute, which offers competitive matching grants to urban agriculture projects that aim to increase food security while also providing nutritional education and job training, released $5 million in funds in 2014. To help develop more data on the sector, NIFA stipulates that grant recipients make their results available to researchers.[50]

Because scalability remains a major limitation for urban agriculture, NIFA also teams up with groups that provide significant amounts of nutritious food to low-income urban residents, such as food rescue operations, food banks and nutrition education programmes. Every day, City Harvest, a food rescue group that has operated in New York City for more than 30 years, picks up about 136,000 pounds of fresh food from restaurants, manufacturers, bakeries and farms and distributes it to 500 community kitchens that serve about 500,000 people.

Although not engaged in urban agriculture, City Harvest shares many of the same goals and initiatives: it prioritises the delivery of nutritious foods, such as fresh produce, meat and dairy; offers nutrition and cooking classes; and hosts farmers' markets that distribute 20,000 pounds of fresh produce twice a month in eight locations around the city.[51] The NGO relies almost entirely on private donations, but NIFA recently awarded the group a five-year supplemental nutrition assistance program (SNAP) education grant to "motivate and mobilise" SNAP-eligible consumers to purchase more produce with their food stamps. The group will draw upon its background in community cooking courses, as well as its relationships with retailers, to offer shopping tips. For 2015, the USDA made $31.5 million in similar grants available through its Food Insecurity Nutrition Incentive (FINI) programme, authorised by the 2014 Farm Bill.[52]

Groups such as Growing Power, operating in Milwaukee and Chicago, have teamed up with city governments to train low-income residents in urban agriculture, and also help them obtain industry certifications, develop distribution plans for their products, and get their enterprises up and running.[53] Its Milwaukee farm—located across the street from a public housing project that is three miles from the nearest grocery store—provides $16 food packages for low-income customers that can feed a family of four for a week.[54]

50 USDA National Institute of Food and Agriculture. "Community Food Projects Competitive Grant Program: 2014 Request for Applications", 2013.

51 Interview with Leslie Gordon, City Harvest's Senior Director of Program Strategy and Operations.

52 USDA. "USDA Awards $31 Million in Grants to Help SNAP Participants Afford Healthy Foods", News Release No. 0084.15.

53 City of Chicago: Mayor's Press Office. "Mayor Emanuel Launches New 'Farmers For Chicago' Network For Chicago Urban Farmers". March 15th 2013.

54 Allison Hagey, "Growing Urban Agriculture", PolicyLink, 2012.

Urban agriculture in the developing world has generated policy support in a variety of forms. With funding from several international agencies, the Food and Agricultural Organization (FAO) of the UN has teamed up with municipalities in a number of Latin American and African countries on "micro-gardening" projects where low-income residents employ intensive vegetable production techniques on small urban plots.[55] Although these gardens benefit the participants, scalability remains an issue—none of the projects reached more than 11,000 households. The decision to support urban agriculture in the developing world is further hindered by a dearth of reliable data about its reach and effectiveness, as many countries can provide only limited, if any, household data.[56]

One of the few studies on the topic was carried out using the World Bank's Rural Income Generating Activities (RIGA) database, which taps into a number of Living Standards Measurement Studies (LSMS) and other nationally representative household data sources for 15 low-income countries in Asia, Africa and Latin America. It determined, with some qualifications, that the number of households earning some income from urban agriculture was often high, "ranging from 11% in Indonesia to nearly 70% in Vietnam and Nicaragua", but in only five countries did it represent more than 10% of total income. The study's most important discovery, perhaps, was a clear association between participation in urban agriculture and improved dietary diversification, which is often used as a proxy for food security for low-income populations.[57]

Its authors concluded the study on a cautionary note, urging policymakers in the developing world to think twice before deciding to shut down urban agriculture projects for public health reasons, as in the absence of a viable alternative food source, doing so could deprive low-income populations of a principal source of dietary diversity. However, they also stopped short of recommending policy support for it, as limited public resources might be better spent on employment promotion, which would improve purchasing power, or on enhancing the efficiency of urban food markets.[58] Evidence from rural areas suggests that the relationship between farming one's own food and improved nutrition is stronger where there is inadequate market access. When access to more diverse foods is less of a problem, the difference in nutrition outcomes for farmers and non-farmers in rural areas is reduced, as non-farmers can purchase the same products farmers grow.[59]

The availability of nationally representative household data in the developing world has improved over the past decade, but a critical element—sustained funding and capacity-building technical support for national statistical agencies—is still necessary to accurately measure the effects of urban agriculture. The LSMS-Integrated Surveys on Agriculture Program, funded by the Gates Foundation and the World Bank, is addressing this void for eight countries in Africa, focusing on issues such as the availability and quality of food consumption, crop production and livestock data.[60] Its survey data include geo-reference points within urban areas, thereby overcoming a major challenge: individual country definitions of urban, peri-urban and rural vary greatly, making it difficult to compare data and understand the true nature of urban agricultural operations.

Although a lack of data and research currently limits general policy recommendations on urban agriculture in the developing world, Dr. Alberto Zezza, a senior economist at the World Bank, recommends that policy decisions on whether to fund urban agriculture, and what type of projects to fund, be tailored specifically to each environment, relying on sound data. In China, for example, concerns over food safety and quality,

55 FAO, "Urban and Peri-urban Horticulture", http://www.fao.org/ag/agp/greenercities/en/projects/index.html

56 Ruth Stewart et al., "What are the impacts of urban agriculture programs on food security in low and middle-income countries?", *Environmental Evidence*, April 2013.

57 Alberto Zezza et al., "Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries", *Food Policy*, August 2010, 267.

58 Ibid.

59 Interview with Dr. Alberto Zezza, senior economist in the World Bank's Development Research Group. See also Carletto, Ruel, Winters, Zezza (eds.), forthcoming. "Farm-level pathways to improved nutritional status", Special Issue of the *Journal of Development Studies*, 2015.

60 Ibid.

coupled with a rising population, often generate a premium of 400-500% on organically grown food, versus an average of around 100-150% in the United States.[61] Such premiums could make investments in urban agriculture more viable—which would be especially helpful to low-income farmers.

61 Interview with Manuela Zoninsein, CEO and founder of Smart Agricultural Analytics.

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