INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
IFPRI

Synopsis

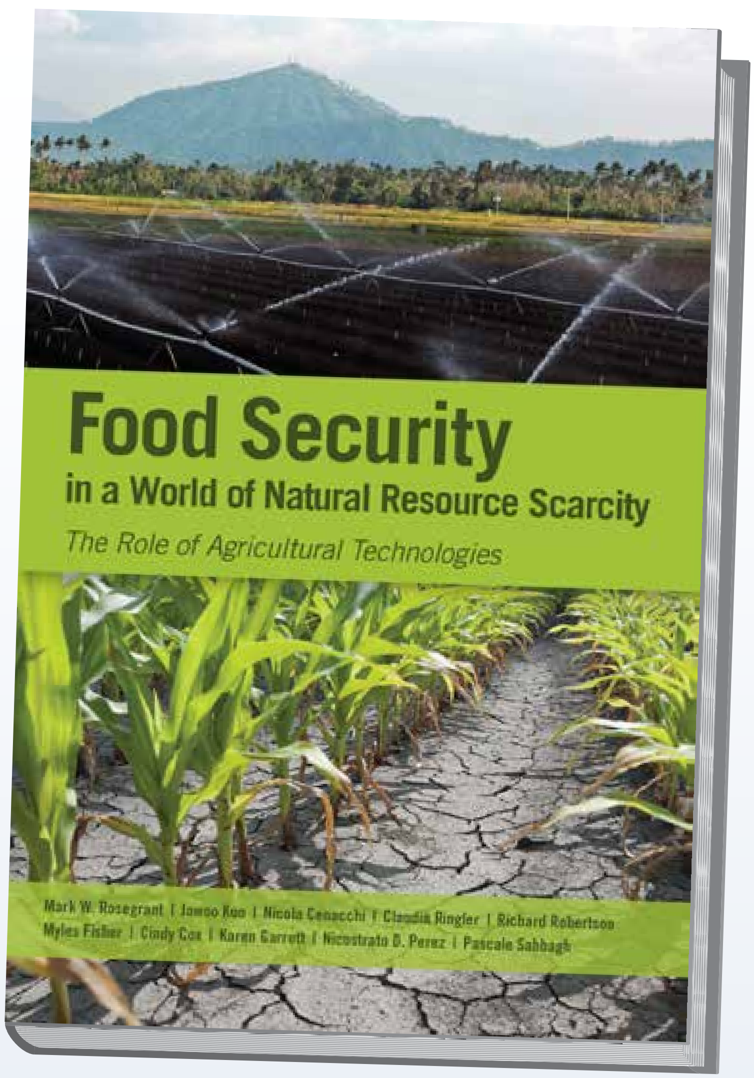
FOOD SECURITY IN A WORLD OF NATURAL RESOURCE SCARCITY

The Role of Agricultural Technologies

Mark W. Rosegrant, Jawoo Koo, Nicola Cenacchi, Claudia Ringler, Richard Robertson, Myles Fisher, Cindy Cox, Karen Garrett, Nicostrato D. Perez, and Pascale Sabbagh

IFPRI issue brief 81
February 2014

Feeding the world in the decades leading up to 2050—decades that will see an increase in food demand spurred by population and income growth and stronger impacts of climate change on agriculture—will require increased and more sustainable agricultural production. To determine how to achieve such production, the authors of the study *Food Security in a World of Natural Resource Scarcity* used a groundbreaking modeling approach to assess the yield and food security impacts of a broad range of agricultural technologies under varying assumptions regarding climate change and technology adoption. Their approach combines process-based crop modeling of agricultural technologies with sophisticated global food demand, supply, and trade modeling. The authors' focus was on the world's three key staple crops: maize, rice, and wheat.



The study compares the effects that different technologies have on crop yields and the use of resources such as harvested area, water, and fertilizers. By modeling technology-induced changes in crop yields, the analysis also helps to explain how the mix of technologies may influence global food markets, particularly for developing countries, by changing food prices and trade flows, as well as calorie availability.

STUDY RESULTS

Determining which technologies may be most promising depends on estimates of economic and population futures as well as on the projected climate change scenario and the specific crop involved. Under the wetter, hotter climate scenario known as MIROC A1B, heat-tolerant crop varieties are projected to produce the highest global yield increase for maize in 2050; varieties that use nitrogen more efficiently produce the highest global yield increase for rice; and no-till farming, which involves minimum or no soil disturbance, is the best option for wheat (Table 1).

Adopting these technologies could have a significant positive impact on food security: the number of food-insecure people in developing countries could be reduced in 2050 by 12 percent (or almost 124 million people) if nitrogen-efficient crop varieties were widely in use; by 9 percent (91 million people) if no-till farming were more

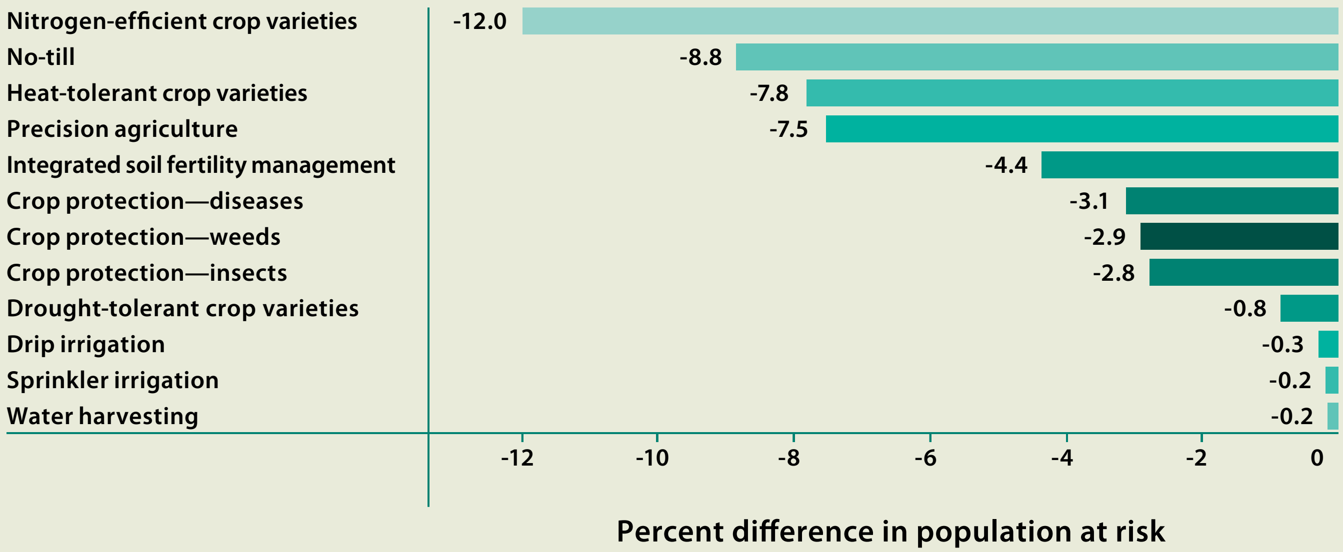
TABLE 1 Global yield changes in 2050, relative to the baseline, under alternative agricultural technologies (economic modeling results)

Technology	Maize (%)	Rice (%)	Wheat (%)
Nitrogen-efficient crop varieties	11.3	20.2	6.2
No-till	15.8		16.4
Heat-tolerant crop varieties	16.1	3.0	9.3
Precision agriculture	3.7	8.5	9.7
ISFM	1.8	6.7	3.8
Crop protection—diseases	2.2	2.8	4.2
Crop protection—weeds	3.1	2.5	3.4
Crop protection—insects	2.6	2.5	3.3
Drought-tolerant crop varieties	1.1	0.1	1.4
Drip irrigation	0.1		0.7
Water harvesting	0.5		0.1
Sprinkler irrigation	0.1		0.4

Source: IMPACT simulations and MIROC A1B climate change scenario.

Notes: ISFM = integrated soil fertility management. Blank fields indicate that the technology is not applicable.

FIGURE 1 Change in 2050 of the number of people at risk of hunger, relative to the baseline scenario, under alternative agricultural technologies



Sources: IMPACT simulations and MIROC A1B climate scenario.

widely adopted; and by 8 percent (80 million people) if heat-tolerant crop varieties or precision agriculture (a set of practices that includes GPS-assisted delivery of agricultural inputs) were adopted (Figure 1).

Since agricultural technology impacts differ substantially by region and, within regions, by country, targeting adoption is important. For several technologies across the three crops, the largest yield gains occur in Africa, South Asia, and parts of Latin America and the Caribbean. Heat-tolerant varieties have the largest potential to increase yields in North America and South Asia; and drought-tolerant crop varieties have the largest potential in Latin America and the Caribbean, the Middle East and North Africa, and Africa south of the Sahara. Crop protection is most effective in Africa south of the Sahara, South Asia, and Eastern Europe. Precision agriculture shows the highest total gains in major production areas in South Asia, the Middle East and North Africa, and parts of Western Europe. Nitrogen-efficient varieties show gains in most developing regions, particularly in South Asia, East Asia and the Pacific, and Africa south of the Sahara. Integrated soil fertility management (ISFM), which combines chemical fertilizers, crop residues, and compost, has the largest potential in low-input regions within Africa, in South Asia, and also in part of East Asia and the Pacific.

In an age of increasing competition for resources and efforts to curb impacts on the environment, technologies that reduce water use and nitrogen runoff gain growing importance; and these benefits, along with the potential for yield increase, need to be taken into consideration to determine which choice may be most appropriate under given climate and soil conditions. Several technologies relevant to these concerns were tested in the study. Advanced irrigation techniques, such as drip and sprinkler, have minimal direct impact on maize and wheat yields but provide substantial water savings; no-till practices provide large yield impacts in some regions, conserve soil moisture, reduce erosion, and may lower nitrogen losses, as can ISFM, which also provides important nutrients for farms; and nitrogen-efficient varieties both have strong yield impacts and may reduce negative environmental impacts from fertilization.

In addition to the individual technologies assessed, the study evaluated a series of joint technology applications that combine elements of traditional agriculture, such as no-till, with modern forms of plant breeding, such as heat- or drought-tolerant crop varieties. Findings show that the combination of no-till with heat tolerance works extremely well for maize and the combination of no-till with precision agriculture achieves high yield boosts for wheat. Finally, stacked technologies (applications of components from all technologies) can successfully boost the yields of all three crops.

THE WAY FORWARD

Adoption of the technologies examined in the study would increase food production and improve food security under climate change. Effective technology use would involve three main steps:

1. *Increasing crop productivity through enhanced investment in agricultural research*. One promising agricultural research area is crop breeding that targets broad-based yield improvement, abiotic stresses such as heat and drought, and biotic stresses such as insects, weeds, and diseases.

2. *Developing and using resource-conserving agricultural management practices*. Technologies and practices such as no-till, ISFM, improved crop protection, and precision agriculture should be rapidly expanded.

3. *Increasing investment in irrigation*. Increased investment in cost-effective irrigation will increase the returns to other technologies. While replacing furrow irrigation with drip and sprinkler irrigation may have the most benefits in terms of water savings rather than yield increases, irrigation in general tends to enhance other technologies' yield impacts. Therefore continued investment in irrigation should go hand-in-hand with new technology adoption.

Effective technology adoption will also require institutional, policy, and investment advances. Countries where land tenure systems are weak or where farmers lack access to inexpensive financing are not favorable environments for technologies that take many years to produce benefits, such as IFSM, no-till, and water harvesting (channeling water to crop fields). Moreover, continued private-sector investment is essential to reaping the benefits of the drought- and heat-tolerant, as well as the nitrogen-efficient, crop varieties. Finally, given that many technologies are knowledge intensive, extension systems must increase knowledge capacity and use innovative tools, such as information and communication technologies.

In addition to these policy steps, the authors suggest several areas for further research. The proper characterization of technologies in crop models should receive more attention—as should the introduction of cost estimates related to technology discovery, development, and dissemination in the field. Future research should also consider scenarios of increased climate extremes, which are not fully reflected in currently available climate scenarios. Additional work should also assess the greenhouse gas emissions and energy requirements of these technologies.

These initiatives, as well as the study's other findings, should be considered by public- and private-sector policymakers as they decide which technology strategies to pursue to secure food security at national, regional, and global levels.

Mark W. Rosegrant (m.rosegrant@cgiar.org) is the director and **Claudia Ringler** (c.ringler@cgiar.org) the deputy director of the Environment and Production Technology Division of the International Food Policy Research Institute (IFPRI), Washington, DC. **Nicostrato D. Perez** (n.perez@cgiar.org) is a senior scientist, **Jawoo Koo** (j.koo@cgiar.org) and **Richard Robertson** (r.robertson@cgiar.org) are research fellows, **Nicola Cenacchi** (n.cenacchi@cgiar.org) is a research analyst, and **Cindy Cox** (c.cox@cgiar.org) is a technical writer in the Environment and Production Technology Division of IFPRI. **Pascale Sabbagh** (p.sabbagh@cgiar.org) is a senior program manager in the CGIAR Research Program on Policies, Institutions, and Markets led by IFPRI. **Myles Fisher** (mylesjfisher@gmail.com) is an emeritus scientist at the Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. **Karen Garrett** (kgarrett@ksu.edu) is a professor in the Department of Plant Pathology at Kansas State University, Manhattan, KS, US.

We thank CropLife International, the US State Department, and the CGIAR Research Program on Policies, Institutions, and Markets for funding this work.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

A member of the CGIAR Consortium | A world free of hunger and malnutrition

2033 K Street, NW, Washington, DC 20006-1002 USA | T. +1.202.862.5600 | F. +1.202.467.4439 | Skype: IFPRIhomeoffice | ifpri@cgiar.org | www.ifpri.org

 ISBN: 978-0-89629-848-4