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Food Security in a World of Natural Resource Scarcity: The Role of Agricultural Technologies

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USAID Bureau for Food Security

Julie A. Howard is the Chief Scientist in the Bureau for Food Security, which leads the implementation of Feed the Future. She also serves as Senior Advisor on Agricultural Research, Extension and Education. Before joining USAID in 2011, she served as the Executive Director and Chief Executive Officer of the Partnership to Cut Hunger and Poverty in Africa. Howard served as a Peace Corps Volunteer in the Dominican Republic. She holds a Ph.D. in Agricultural Economics from Michigan State University, and master's and undergraduate degrees from the University of California, Davis, and The George Washington University.

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Mark W. Rosegrant is the Director of the Environment and Production Technology Division at IFPRI in Washington, DC. With a PhD in Public Policy from the University of Michigan. He currently directs research on climate change, water resources, sustainable land management, genetic resources and biotechnology, and agriculture and energy. He is the author or editor of 7 books and over 100 papers in agricultural economics, water resources, and food policy analysis. Dr. Rosegrant is a Fellow of the American Association for the Advancement of Science; and a Fellow of the Agricultural and Applied Economics Association.

Food Security in a World of Natural Resource Scarcity:

The Role of Agricultural Technologies

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Project Overview

Business as Usual: Challenges and Threats = Continued Scarcity

- **Challenges**
  - Climate change
  - Water scarcity
  - Biofuel demand
  - Income
  - Population growth

- **Growing threats** to:
  - Land
  - Environmental preservation
  - Water
  - Biodiversity

- **Enhanced investment in agricultural research + technological change** → Game-changer

- **Lack sufficient knowledge**
  - Disaggregated impacts of specific technologies by country
  - Agroclimatic zone

Technology Assessment Scope

- Global & Regional
- **Eleven technologies**
- Three Crops
  - Wheat
  - Rice
  - Maize

- No-Tillage
- Integrated Soil Fertility Management
- Organic Agriculture
- Precision Agriculture
- Crop Protection
- Drip Irrigation
- Sprinkler Irrigation
- Water Harvesting
- Drought Tolerance
- Heat Tolerance
- Nitrogen Use Efficiency

Agricultural Technologies

- **No-till**: Minimal or no soil disturbance, often in combination with retention of residues, crop rotation, and use of cover crop
- **Integrated soil fertility management**: A combination of chemical fertilizers, crop residues, and manure/compost
- **Precision agriculture**: GPS-assisted delivery of agricultural inputs as well as low-tech management practices that aim to control all field parameters, from input delivery to plant spacing to water level
- **Organic agriculture**: Cultivation with exclusion of or strict limits on the use of manufactured fertilizers, pesticides, growth regulators, and genetically modified organisms
- **Water harvesting**: Water channeled toward crop fields from macro- or microcatchment systems, or through the use of earth dams, ridges, or graded contours
- **Drip irrigation**: Water applied as a small discharge directly around each plant or to the root zone, often using microtubing

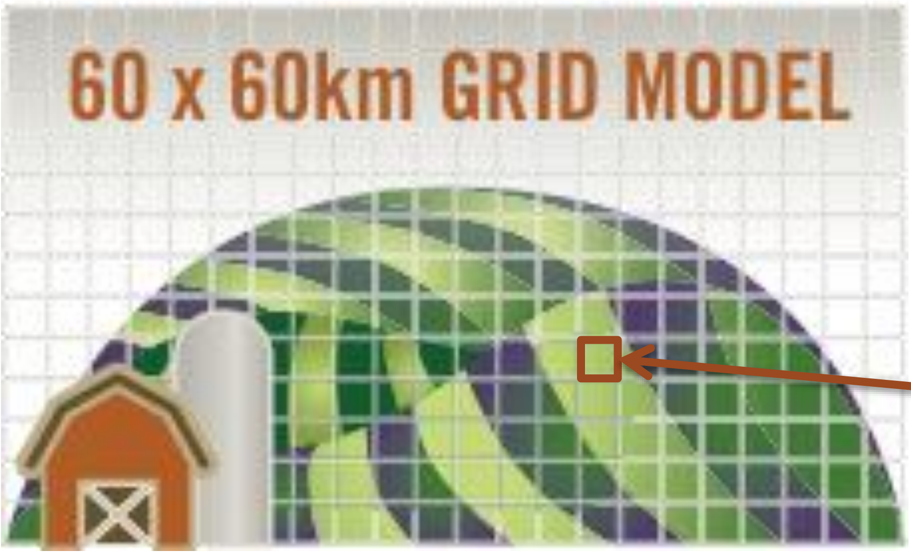
Agricultural Technologies

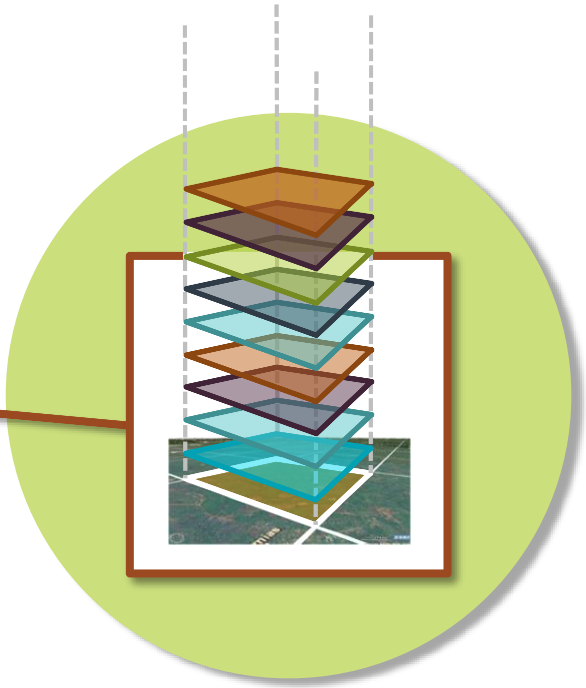
- **Sprinkler irrigation**: Water distributed under pressure through a pipe network and delivered to the crop via overhead sprinkler nozzles
- **Heat tolerance**: Improved varieties showing characteristics that allow the plant to maintain yields at higher temperatures
- **Drought tolerance**: Improved varieties showing characteristics that allow the plant to have better yields compared with regular varieties due to enhanced soil moisture uptake capabilities and reduced vulnerability to water deficiency
- **Nitrogen-use efficiency**: Plants that respond better to fertilizers
- **Crop protection**: The practice of managing pests, plant diseases, weeds and other pest organisms that damage agricultural crops

Modeling Tools

- **DSSAT**
  - Biophysical model - assesses impact of single technology or technology mix
    - Productivity (yields)
    - Resource use (water, N losses)
- **IMPACT**
  - Global economic agricultural model - assesses changes in productivity due to technology adoption
    - Food production, consumption, trade
    - International food prices
    - Calorie availability, food security

High Resolution of Analysis





Resolution of Grid:

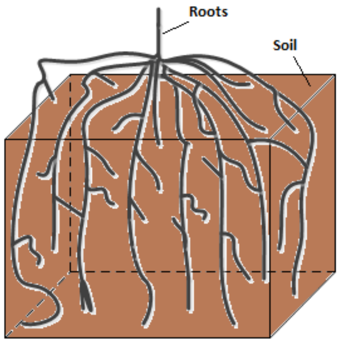
- 30 arc-minute, or 0.5 degree (60 km by 60 km)
- 95,280 cells globally
- **21,385 cells** covering crop land extent for three crops simulated in this study

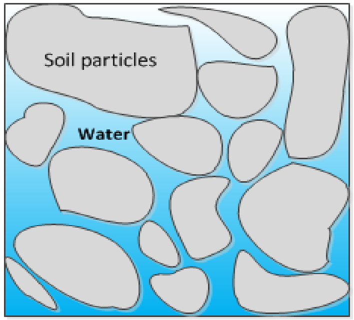
Management Scenarios

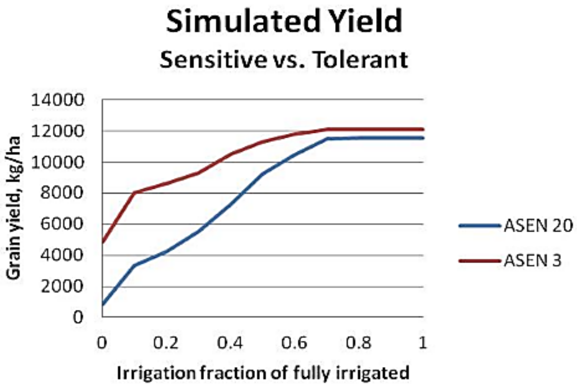
- **Business-as-usual scenario**
  - Country/crop/input system-specific inorganic fertilizer application rate
  - Furrow irrigation, where irrigation is adopted
  - Sub-optimal planting density & sub-optimal planting window
  - Conventional tillage, where no-till is not yet adopted
  - Representative, optimal varieties based on agro-ecological conditions
  - Current, actual yield loss due to biotic constraints
- **Technology scenarios**
  - Specific representation of each technology
  - Area of adoption in 2050 depends on positive yield impact of technology
- **Climate change scenarios 2050s**
  - MIROC A1B (used in this presentation)
  - CSIRO A1B

Sample Technology Specification:
Drought Tolerance

- Increased root volume
  - Implemented by increasing root growth factor parameters
- Enhanced root water extraction capability
  - Implemented by decreasing lower limit of available soil moisture parameters
- For maize, less sensitive to ASI (anthesis to silking interval)
  - Implemented by modifying the existing model to have differential ASI as a cultivar trait, driven by shoot growth rate*

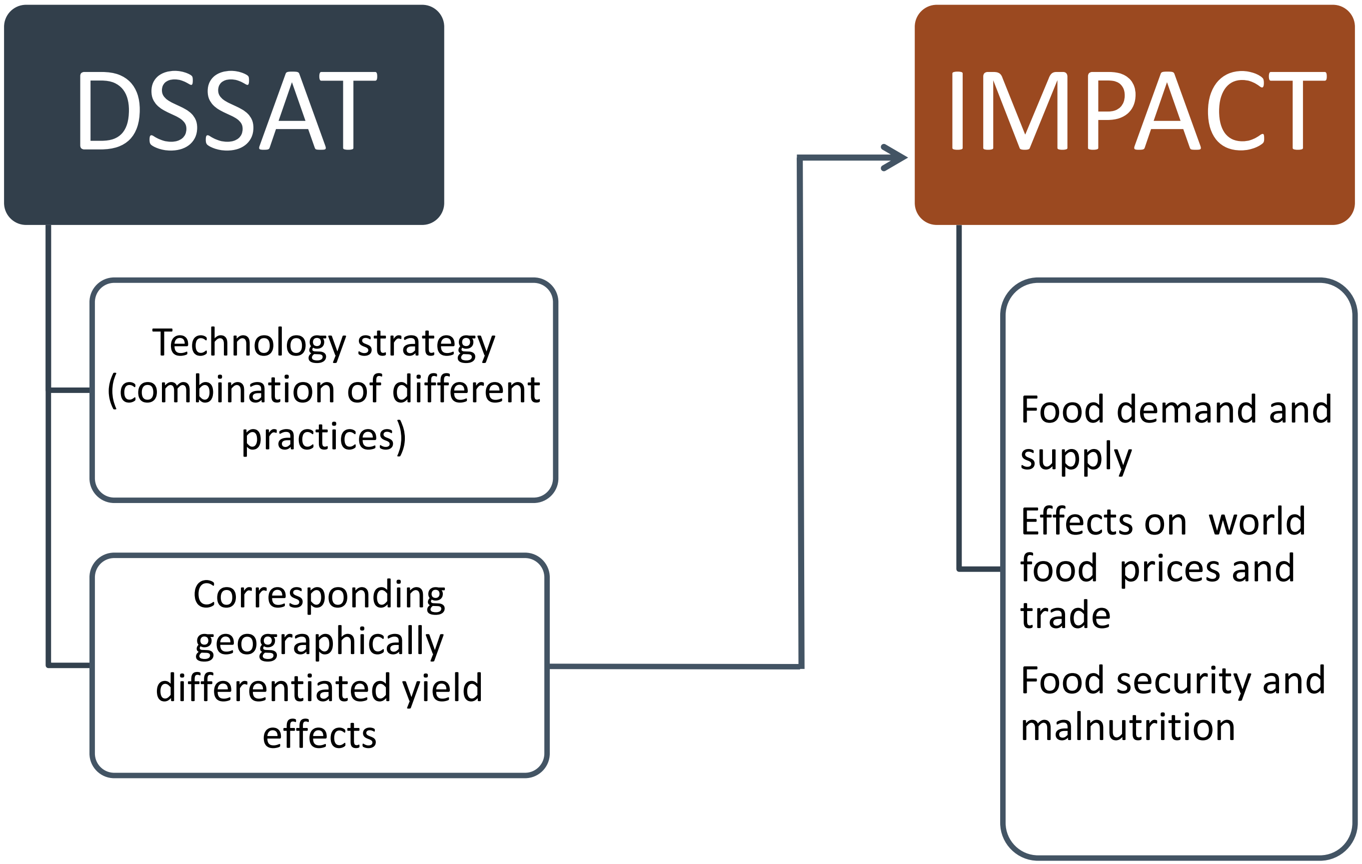






* In collaboration with Ag. Bio. Engineering Dept., University of Florida

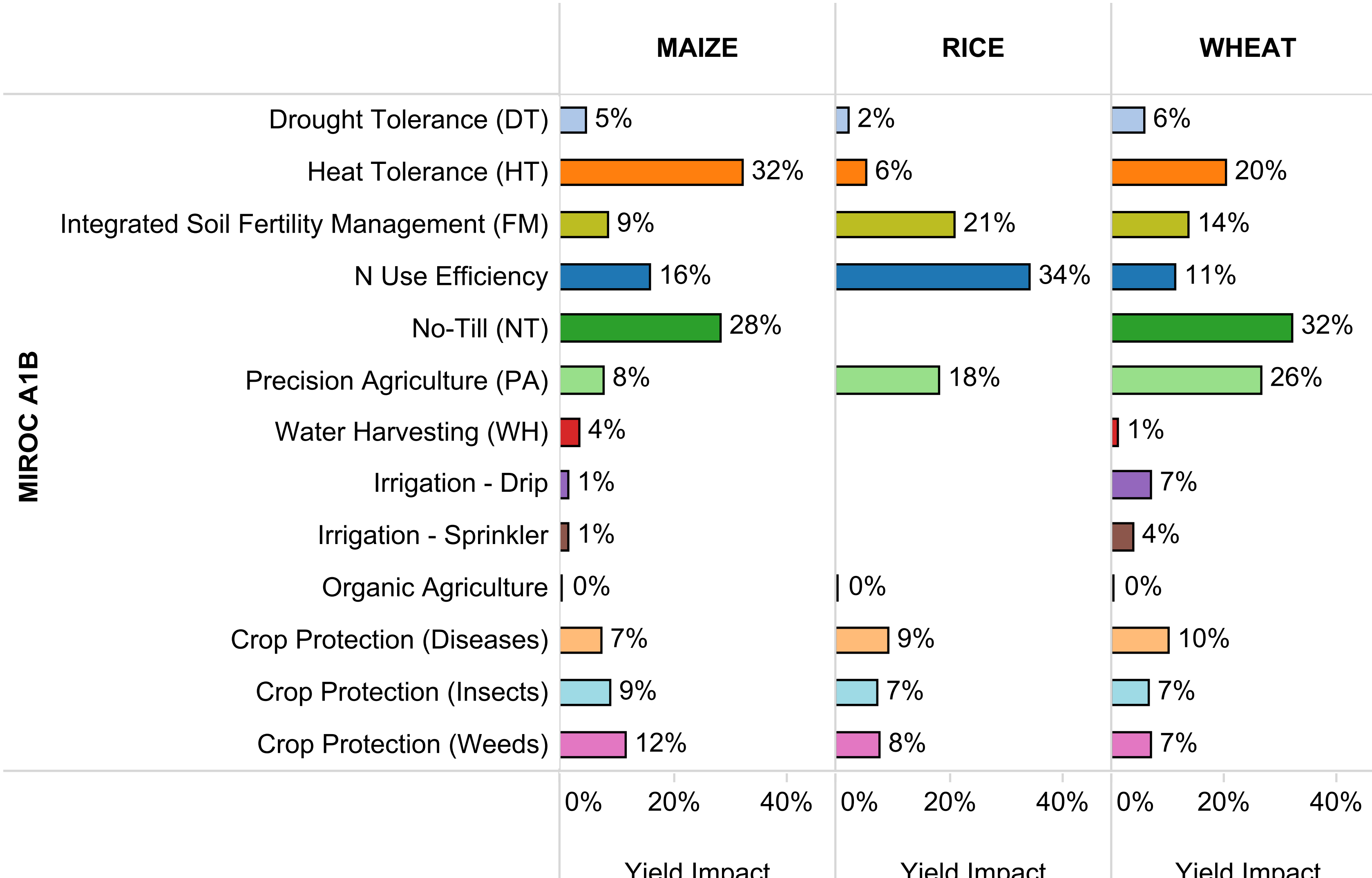
Crop model (DSSAT) linked with Global Partial Equilibrium Agriculture Sector Model (IMPACT)



Results

Global DSSAT Results

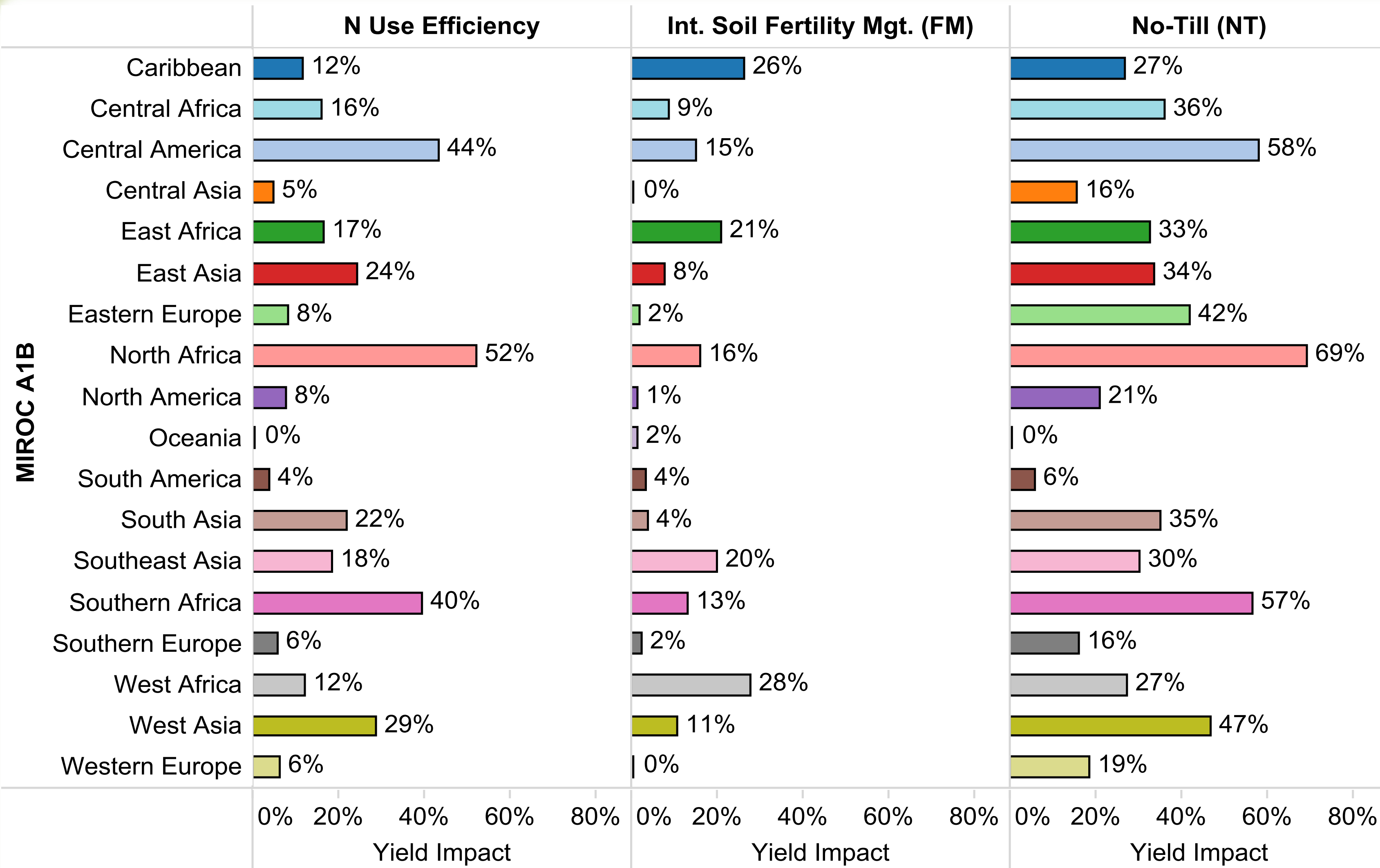
Yield Change (%) – Maize, Rice, & Wheat, 2050 vs. Baseline



Source: Rosegrant et al. 2014.

Regional DSSAT Results, Maize:

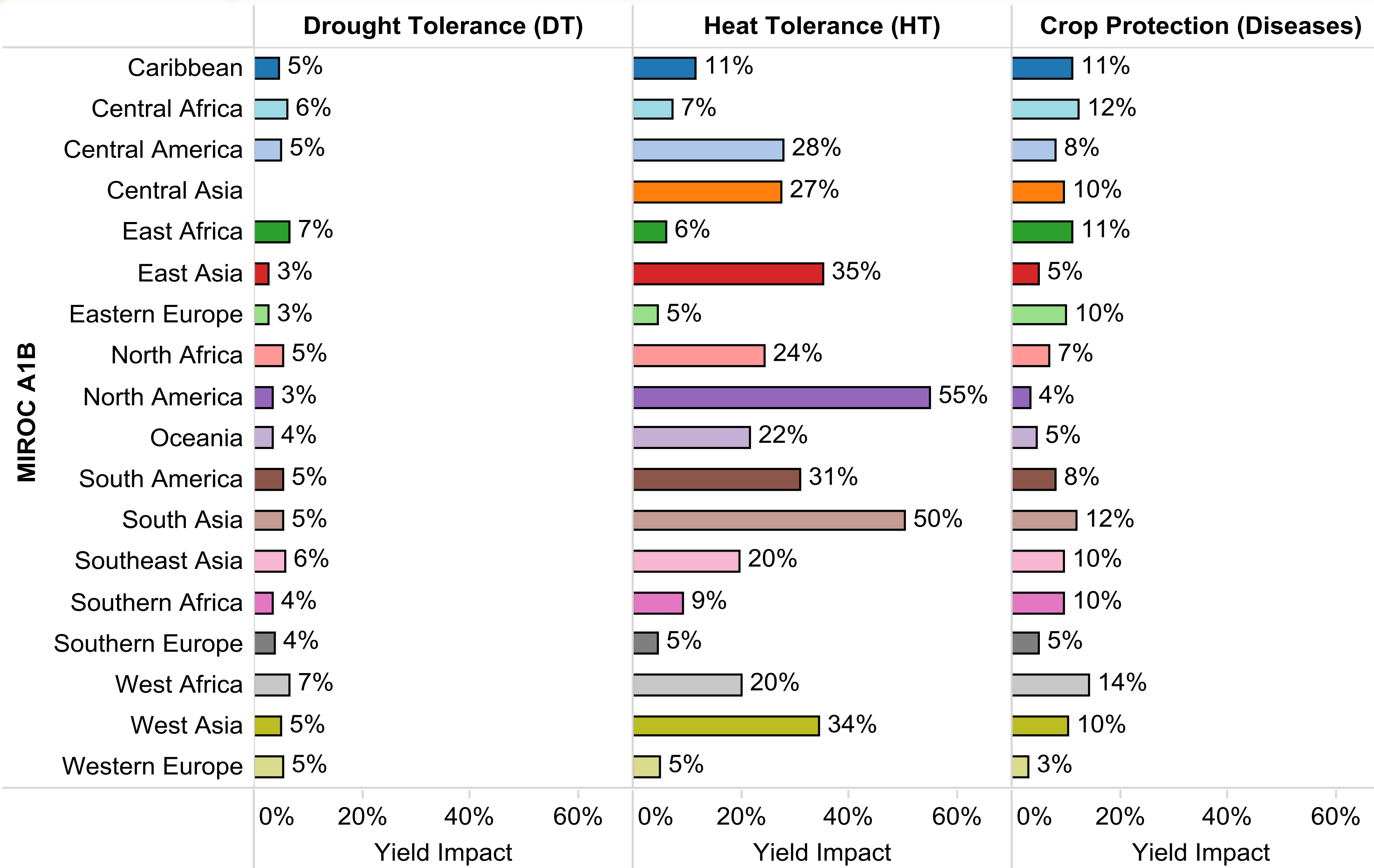
NUE, ISFM, and No-till, 2050 vs. Baseline



Source: Rosegrant et al. 2014.

Regional DSSAT results, Maize:

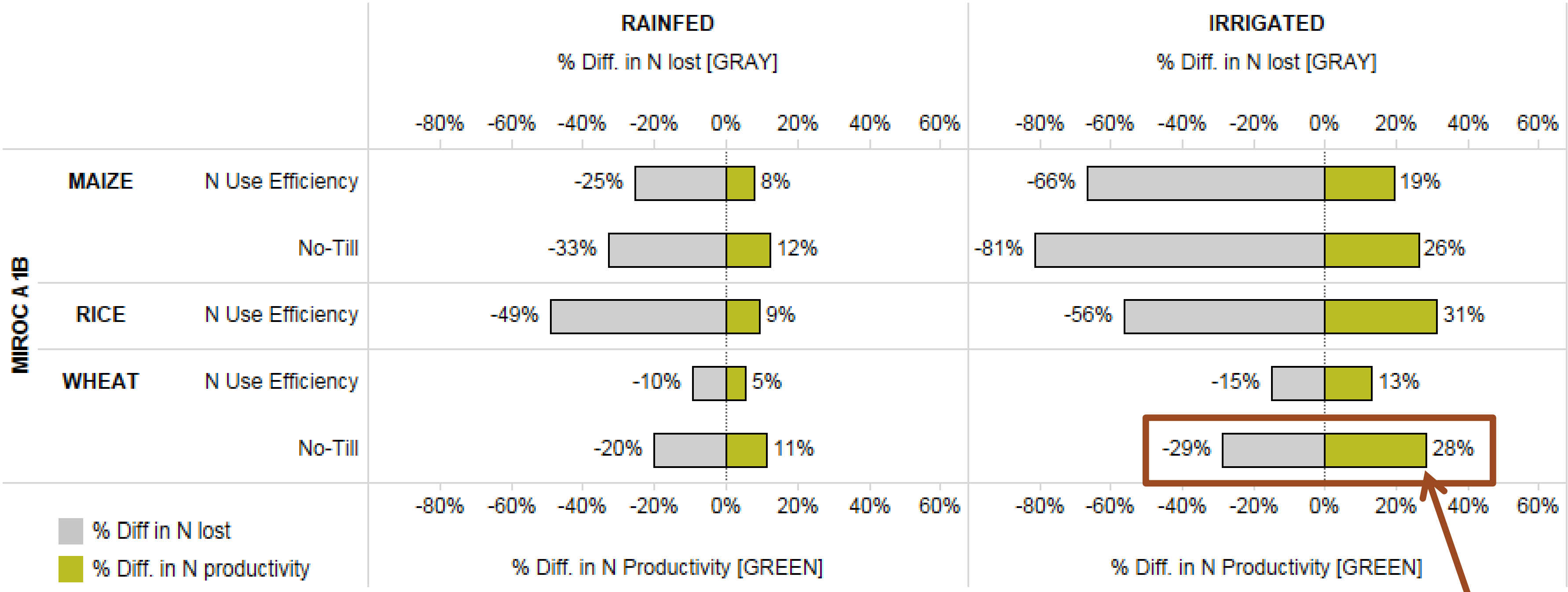
Drought Tolerance, Heat Tolerance and Crop Protection (disease), 2050, compared to baseline



Source: Rosegrant et al. 2014

Efficient use of resources:

Change (%) in N Productivity – **Maize, Rice, Wheat.** Irrigated vs. Rainfed, 2050 vs. Baseline (DSSAT)



(Compared to the business-as-usual)

29% less nitrogen losses

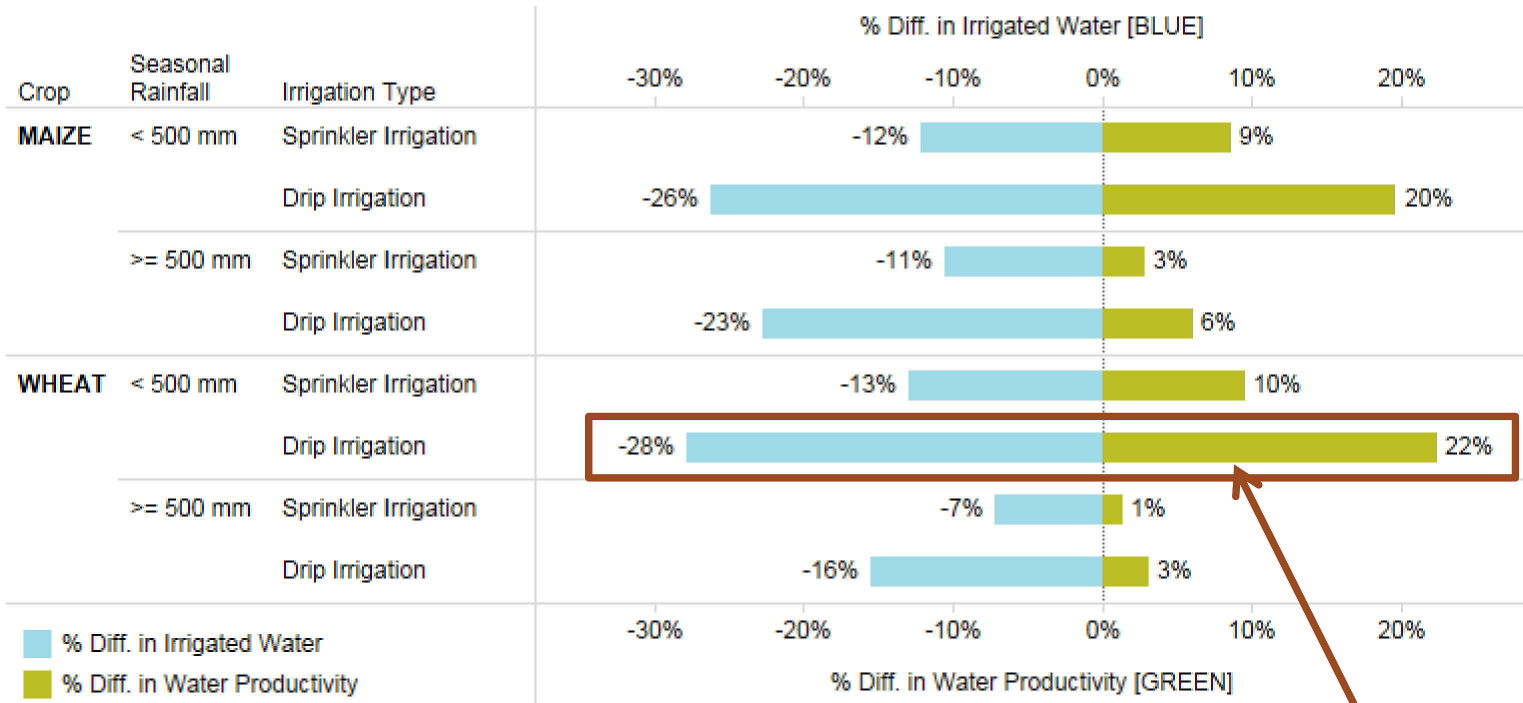
→ 28% more N productivity

Benefits include reduced N losses, increased N productivity.

Source: Rosegrant et al. 2014.

Efficient use of resources :

Change in Site-specific Water Use – Irrigated **Maize, Wheat**



(Compared to the conventional furrow irrigation)

28% less water applied

→ 22% more water productivity

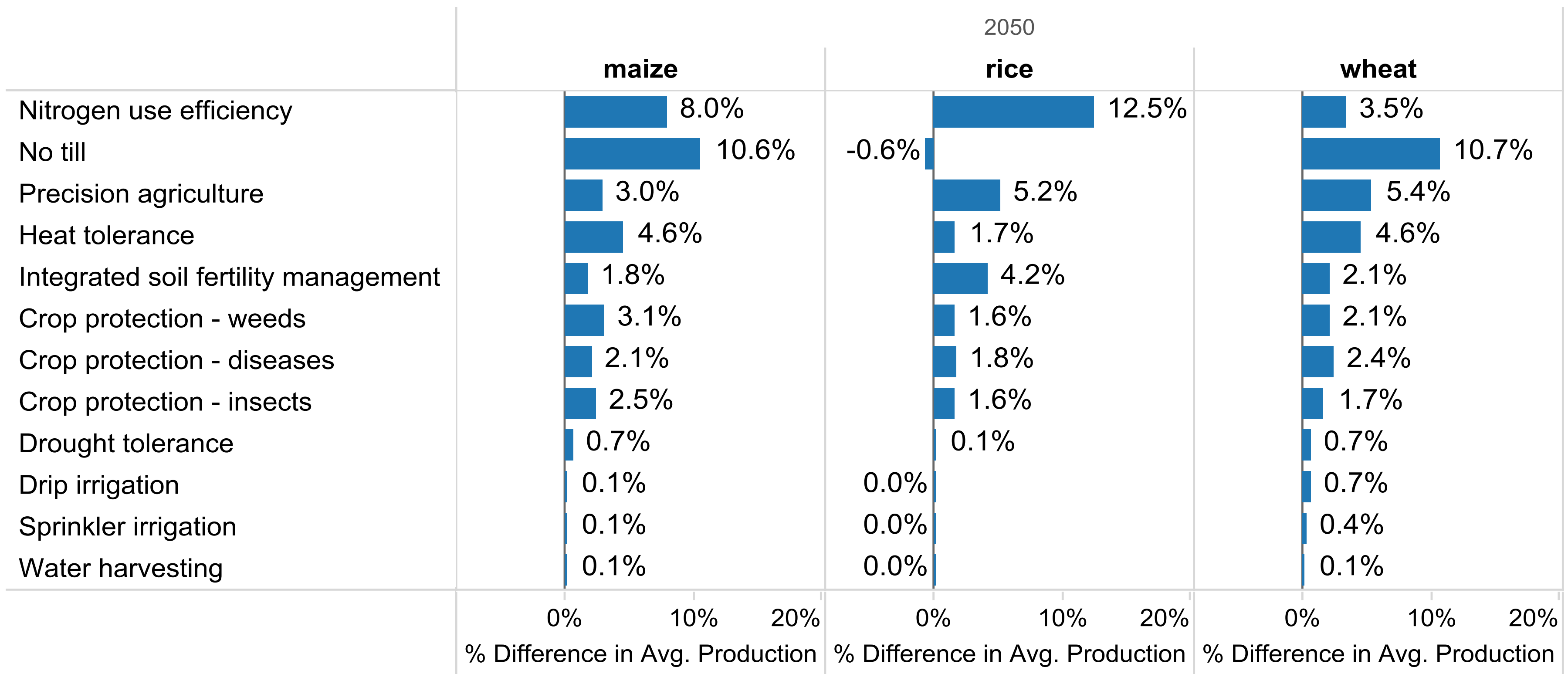
Prominent impacts of

Improved Irrigation Technologies

- Increased water savings (less water used)
- Increased water productivity (more biomass produced per unit water input)

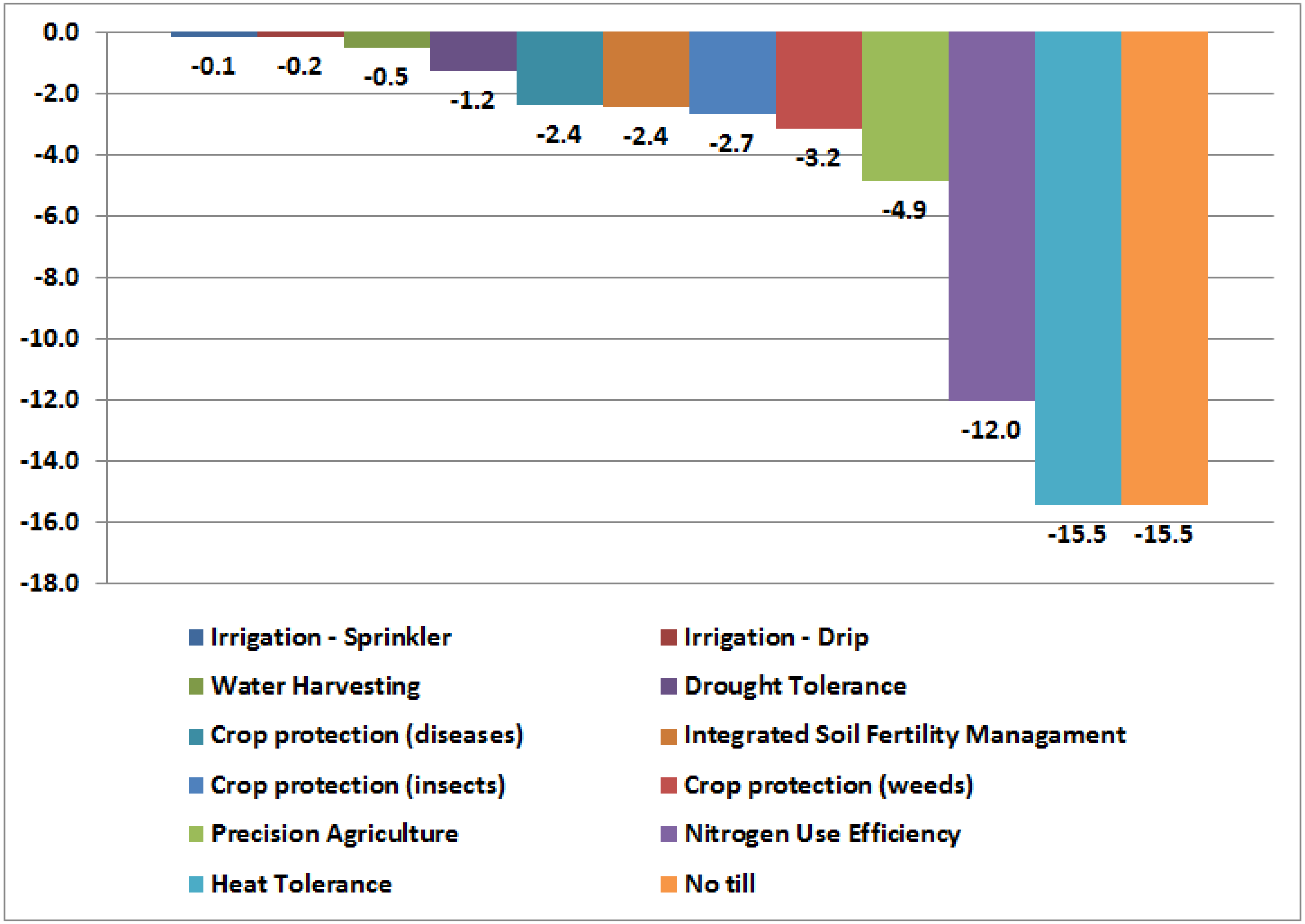
Source: Rosegrant et al. 2014.

Percent Change in Total Production, Developing Countries: Maize, Rice, Wheat, 2050 with Technology vs. 2050 Baseline (IMPACT)



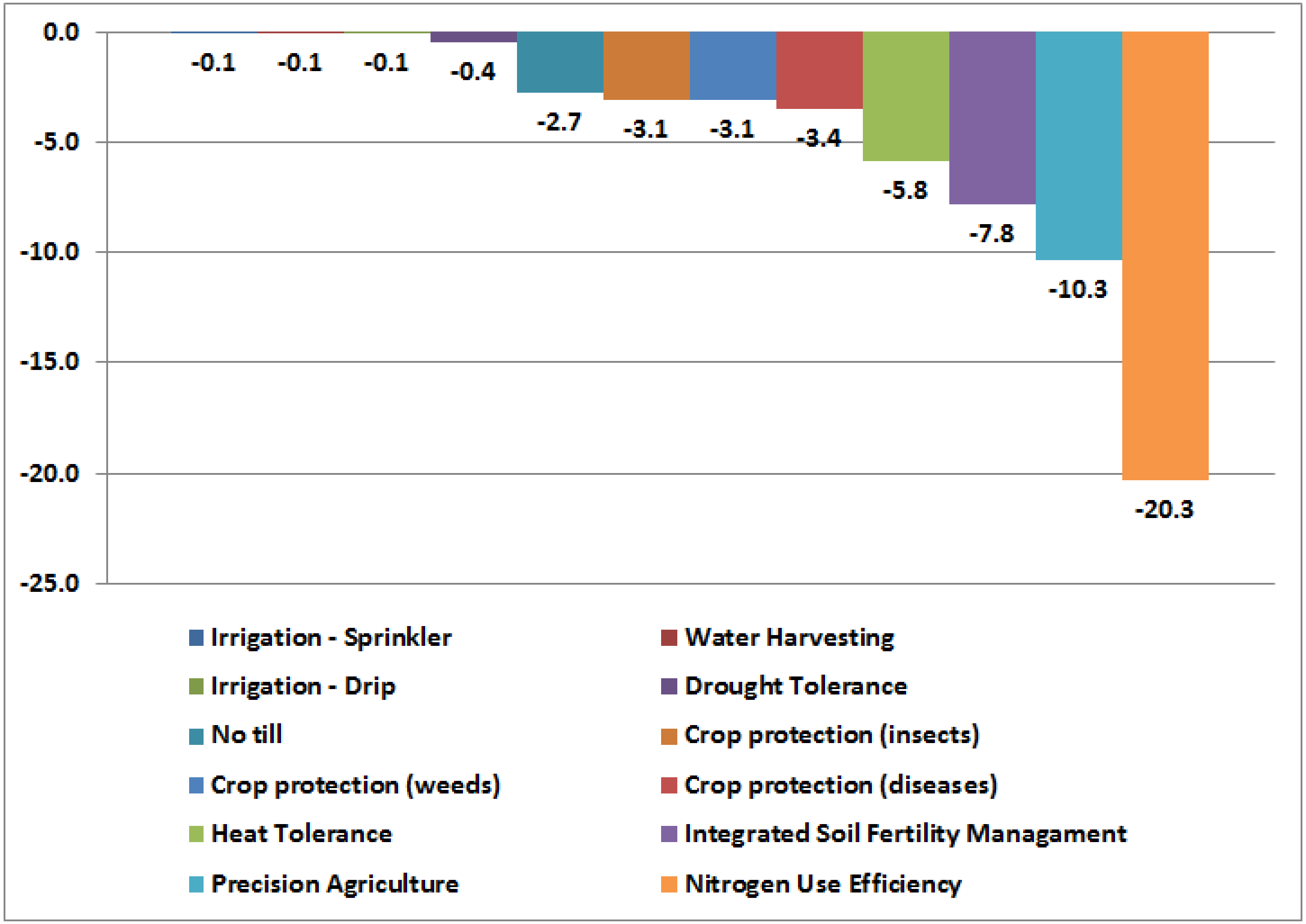
Source: Rosegrant et al. 2014.

Percent Change in World Price, Maize:
2050 with Technology vs. 2050 Baseline (IMPACT)



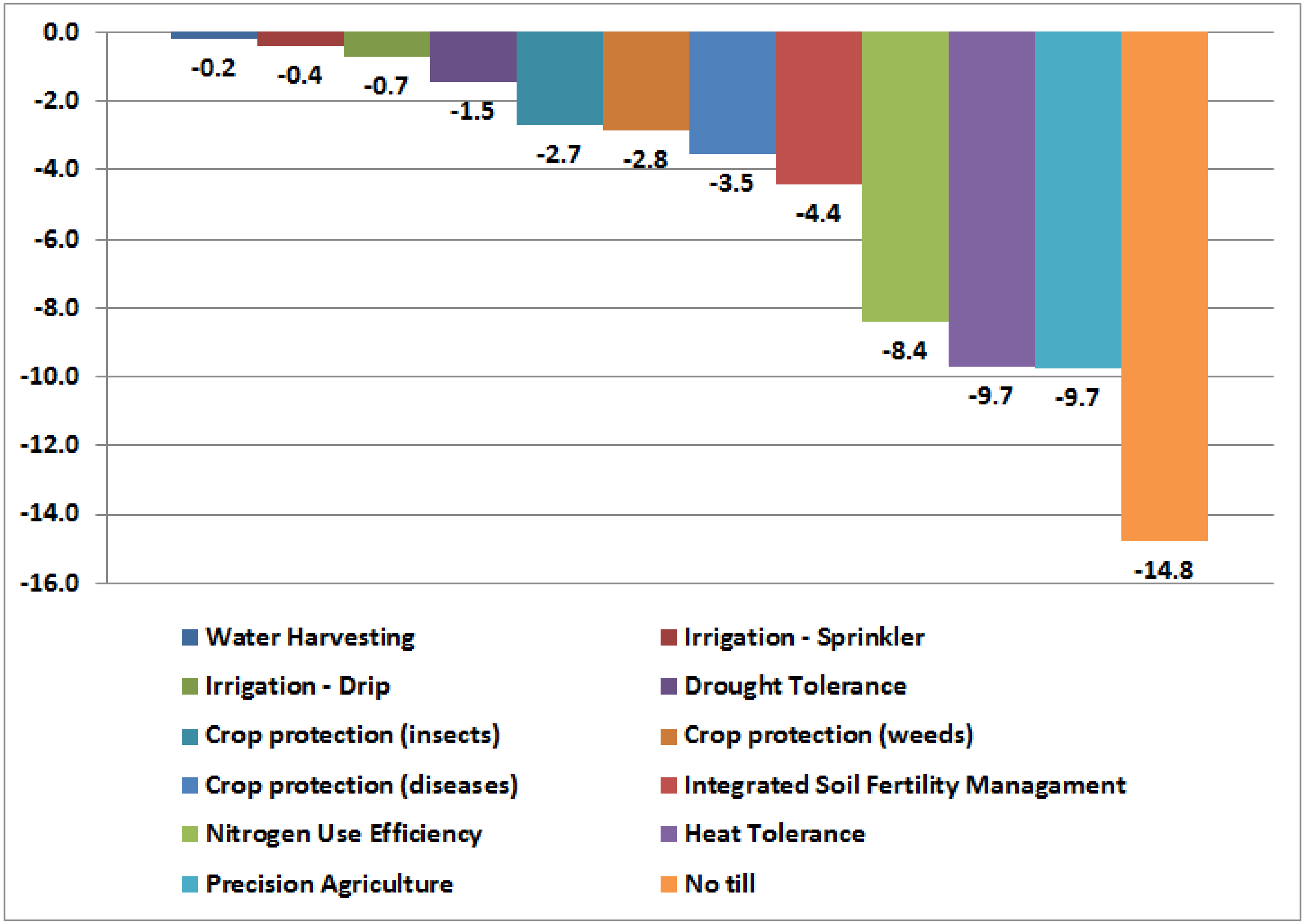
Source: Rosegrant et al. 2014.

Percent Change in World Price, Rice:
2050 with Technology vs. 2050 Baseline (IMPACT)



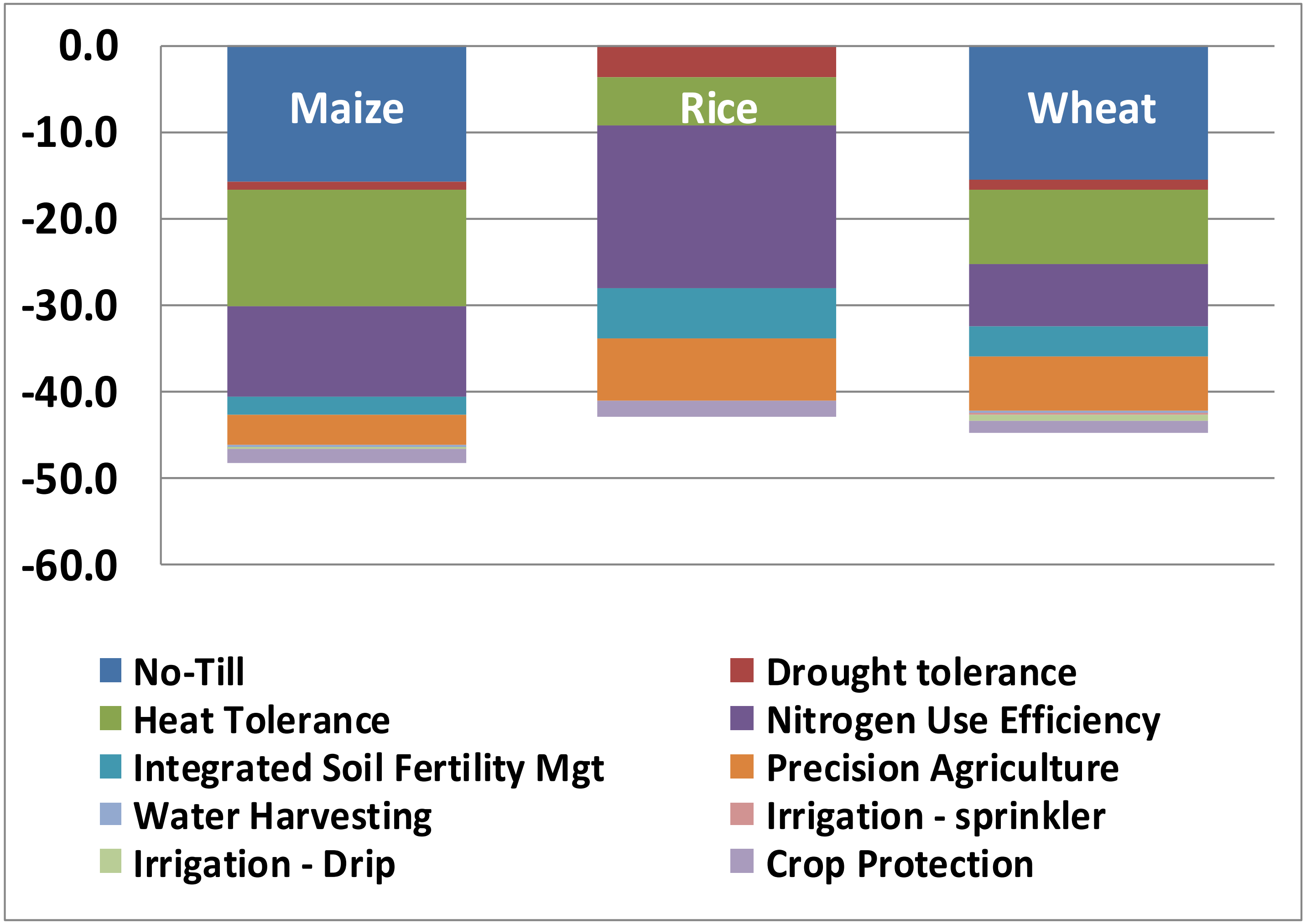
Source: Rosegrant et al. 2014.

Percent Change in World Price, Wheat:
2050 with Technology vs. 2050 Baseline (IMPACT)



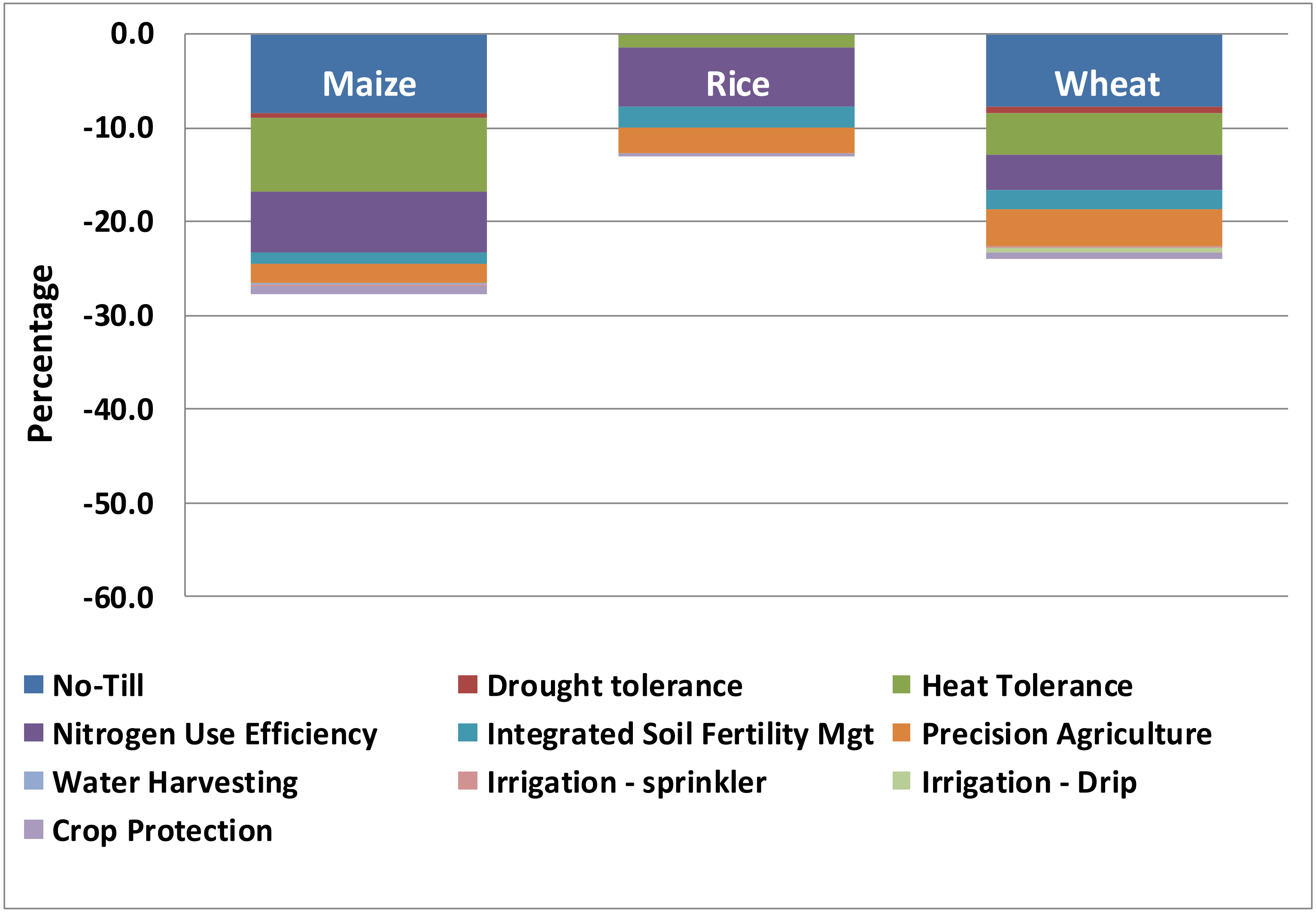
Source: Rosegrant et al. 2014.

Price Effects of Technologies, 2050, compared to Baseline: Global – Combined Technologies



Source: Rosegrant et al. 2014.

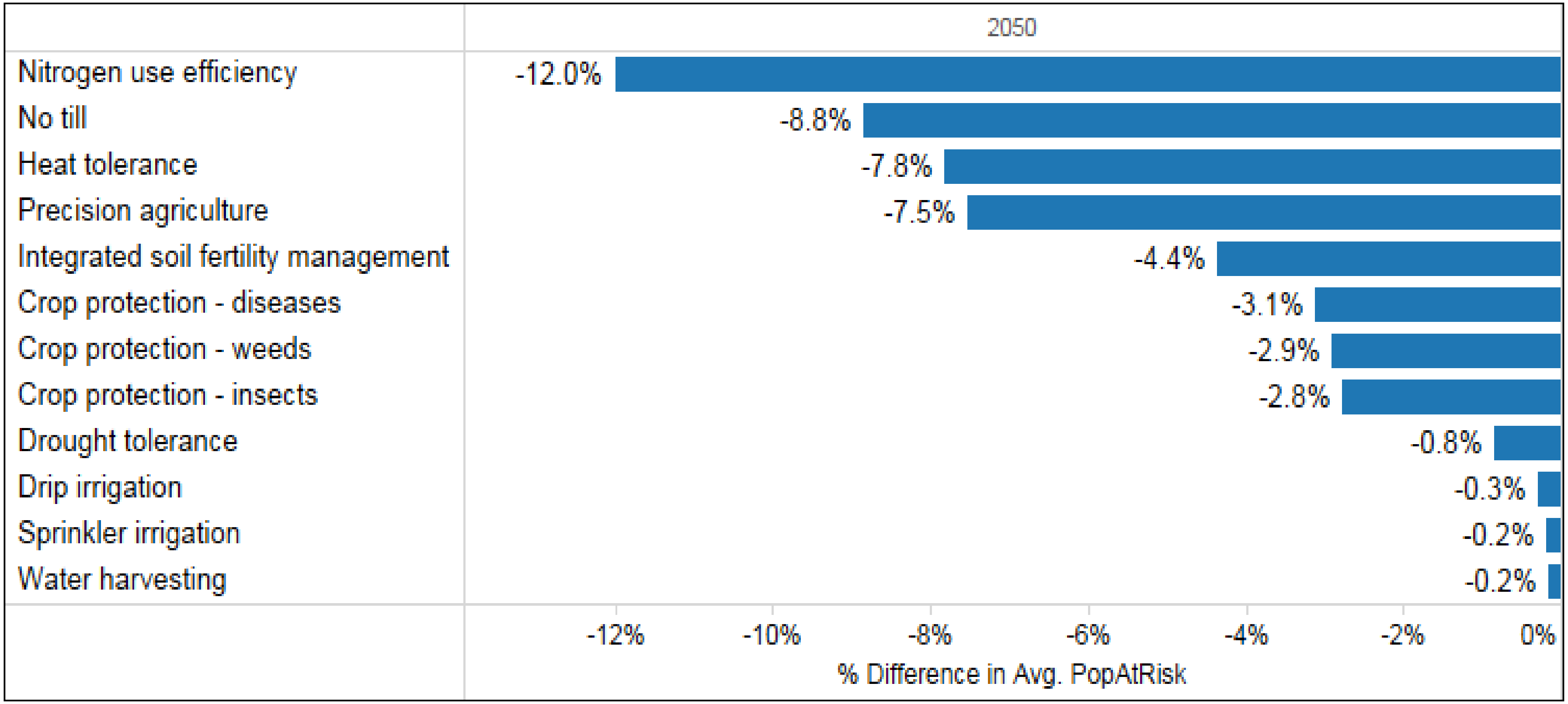
Percent Change in Harvested Area, 2050, Compared to Baseline: Global – Combined Technologies



Source: Rosegrant et al. 2014.

Change (%) in Population at Risk of Hunger, Developing Countries:

2050 with Technology vs. 2050 Baseline (IMPACT)



Source: Rosegrant et al. 2014.

Key Messages

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Key Messages

- Adoption of this set of technologies significantly reduces projected food prices in 2050 compared to the climate change baseline
- Farmer adopters will increase real income because technological change is faster than price decline
- The number of people at risk of hunger could be reduced by 40% in 2050 compared to the baseline with adoption of combined technologies under feasible adoption pathways

Key Messages

- Improved land management (No-till, precision agriculture, integrated soil fertility management)
  - Large yield impacts in many regions
- Nitrogen use efficiency in new varieties
  - Strong yield impacts
  - Reduces negative environmental impacts from fertilization
- Heat tolerant varieties
  - Reduce projected negative impacts of climate change
- Drought tolerant varieties
  - Perform as well as susceptible varieties under no drought stress
  - Significant yield benefits under drought conditions

Key Messages

- **Crop protection** has strong positive yield impacts
- Technology impacts are higher with **irrigation**
- Large regional differences in agricultural technology impacts
- Important to target specific investments to specific regions
  - Heat tolerance to North America and South Asia
  - Drought tolerance to LAC, MENA, SSA
  - Crop protection to SSA, SA, and Eastern Europe

Key Messages

- Organic agriculture is not a preferred strategy for the 3 crops; has a role in niche high-value markets
- Given growing natural resource scarcity, technologies that reduce resource use are important:
  - **No-till**
  - **Integrated soil fertility management**
  - **Nitrogen use efficiency**
  - **Precision agriculture**
  - **Drip and sprinkler irrigation**

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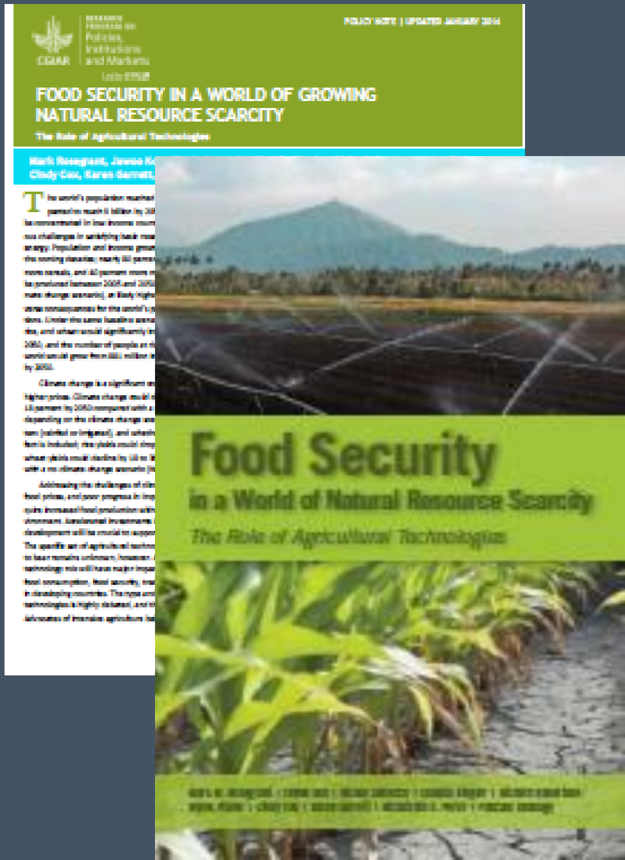
Food Security in a World of Natural Resource Scarcity:

The Role of Agricultural Technologies

We find strong positive food security impacts for almost all the agricultural technologies studied---but getting technologies to farmers is a complex undertaking. However, we must act and act fast, as the cost of inaction could be dramatic for the world's food-insecure and our planet's future.



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Microlinks MPEP Seminar Smallholders in Value Chains | March 27

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