AGRICULTURAL TECHNOLOGIES FOR GLOBAL FOOD SECURITY

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Outline

- Advanced Agricultural Technologies
- Modeling Tools to Assess the Potential for Advanced Technologies
- Results and Analysis
- Constraints and Challenges to Realize the Potential
- Conclusions and Policy Recommendations

A New Age of Advanced Agricultural Technology?

- Technological change and productivity growth in agriculture has been strong in much of the world
- Rapid technological change outside of agriculture is creating new potential for technological change in agriculture
- Genetics, automation, sensors, and IT could give a big technological advantage to developed and middle-income countries, **but** there is potential for leap-frogging if policies and enabling conditions are improved
- Disruptive new technologies are likely to be labor-saving, create economies of scale that could put pressure to consolidate land ownership or operational size of farms, and lead to fundamental changes in contract farming
- What are the potential benefits, constraints, and policies to promote new technologies?

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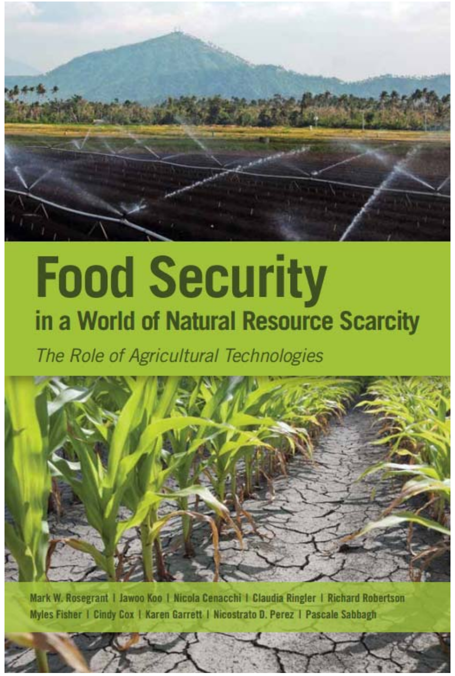
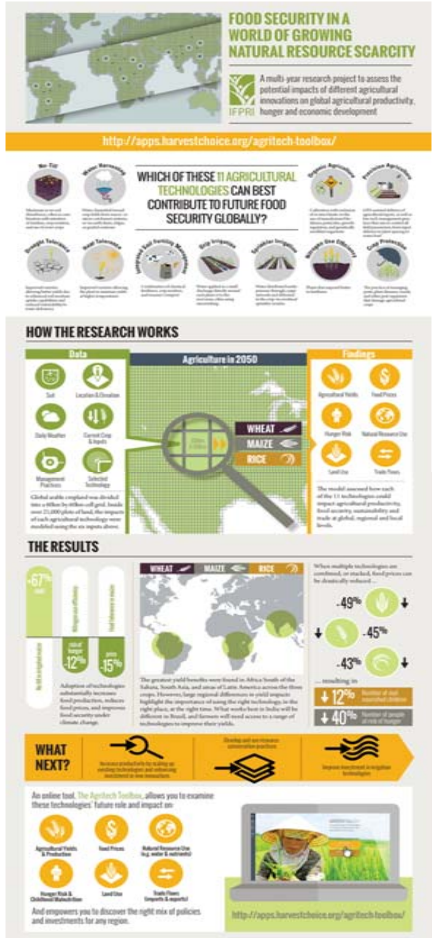
Potential Impact of Agricultural Technology Adoption on Global Food Security

- Impacts of agricultural technologies on farm productivity, prices, hunger, and trade flows were site-specifically estimated using DSSAT biophysical model linked with IMPACT global partial equilibrium agriculture sector model.





Rosegrant, M.W., J. Koo, N. Cenacchi, C. Ringler, R. Robertson, M. Fisher, C. Cox, K. Garrett, N.D. Perez, and P. Sabbagh. 2014. ***Food security in a world of natural resource scarcity: The role of agricultural technologies.*** *IFPRI, Washington, D.C.*

http://www.ifpri.org/publication/food-security-world-natural-resource-scarcity

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Technology Assessment Scope

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

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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

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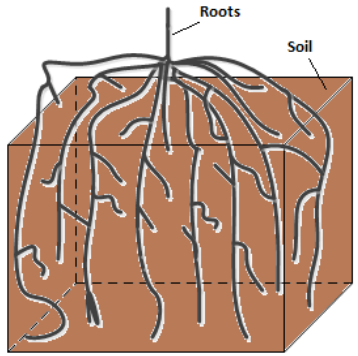
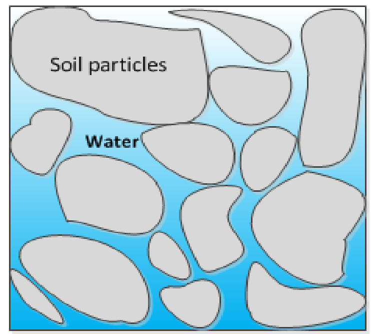
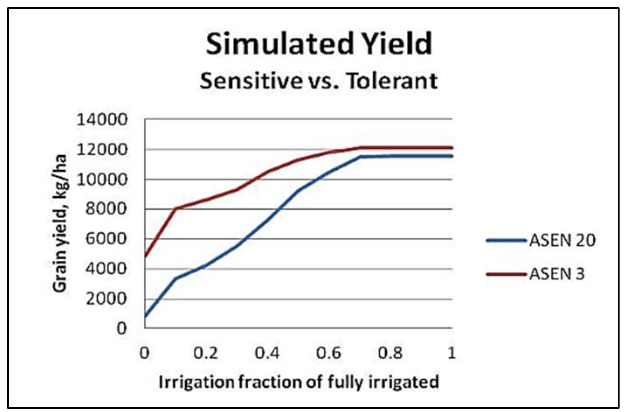
Sample Technology Specification:
Drought Tolerance

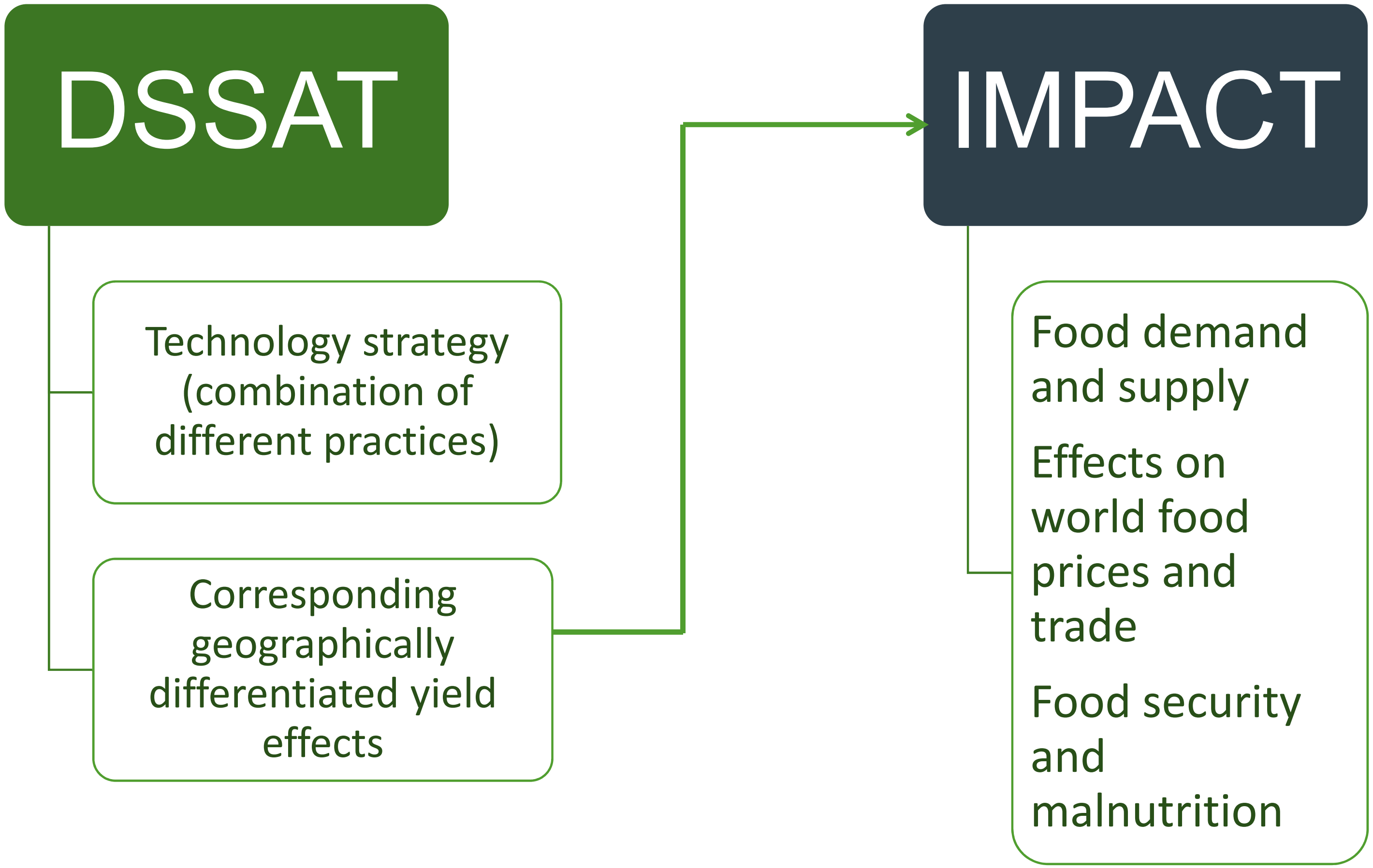
- Increased root volume
  - Implemented by increasing root growth factor parameters
- Enhanced root water extraction capability
  - Implemented by decreasing lower limit of available soil moisture parameters
- For maize, less sensitive to ASI (anthesis to silking interval)
  - Implemented by modifying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







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

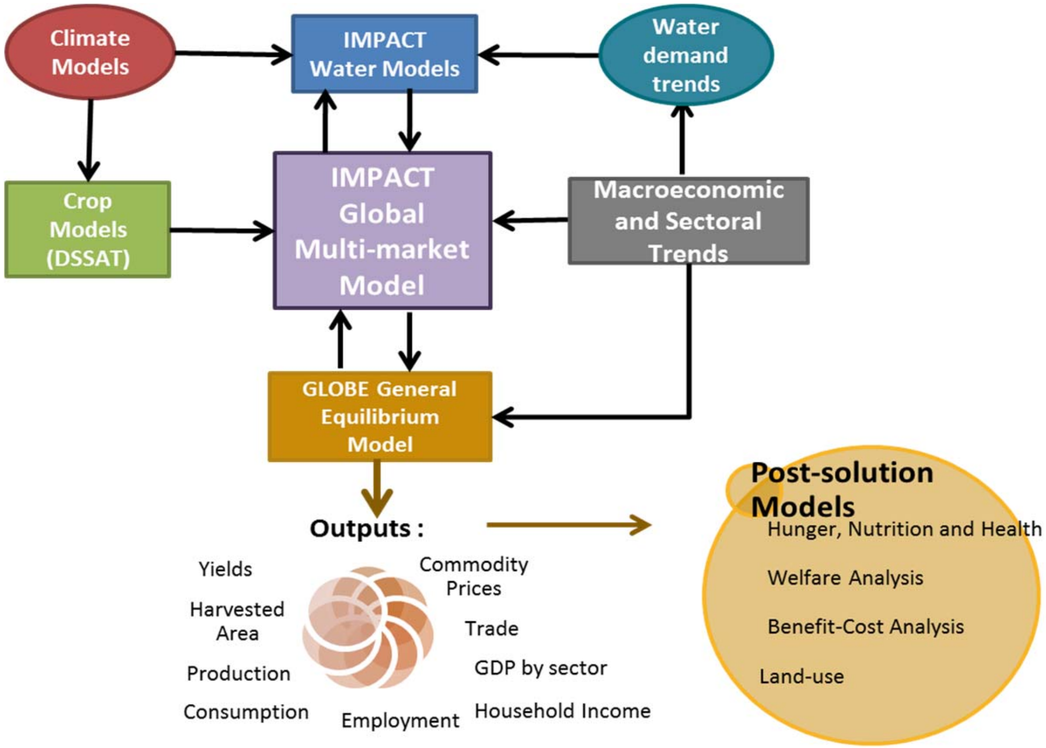


DSSAT Crop Models

- Simulate plant growth and crop yield by variety day-by-day, in response to
  - Temperature
  - Precipitation
  - Soil characteristics
  - Applied nitrogen
  - CO_2 fertilization
  - Other management factors
- DSSAT-based simulations at crop-specific locations (using local climate, soil and topographical attributes)

IFPRI's IMPACT Modeling System

Exploring alternative climate and investment futures

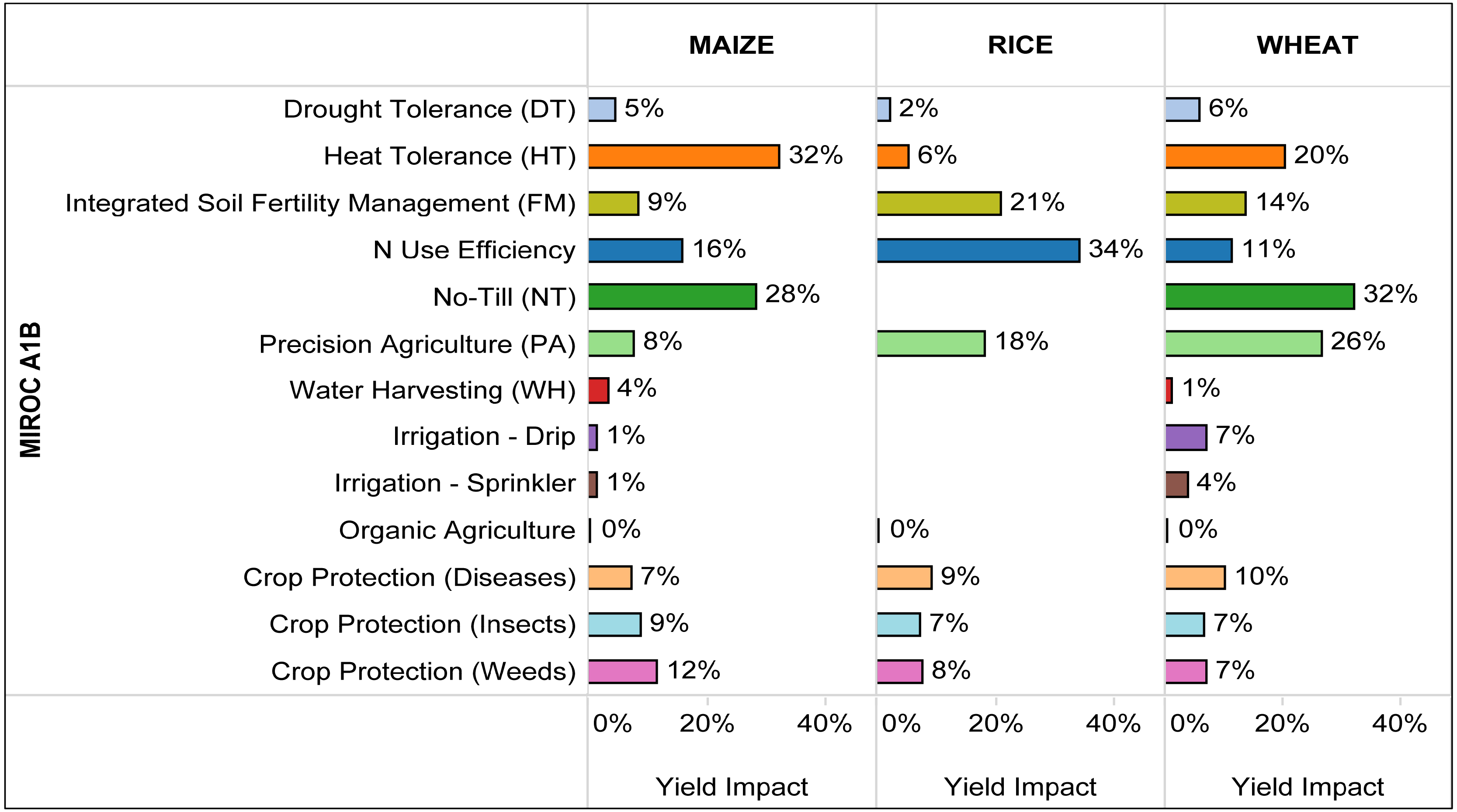


- Linked climate, water, crop and economic models
- Estimates of production, consumption, hunger, and environmental impacts
- High level of disaggregation
  - 159 countries
  - 154 water basins
  - 60 commodities

Source: Robinson et al. (2015)

Global DSSAT Results

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

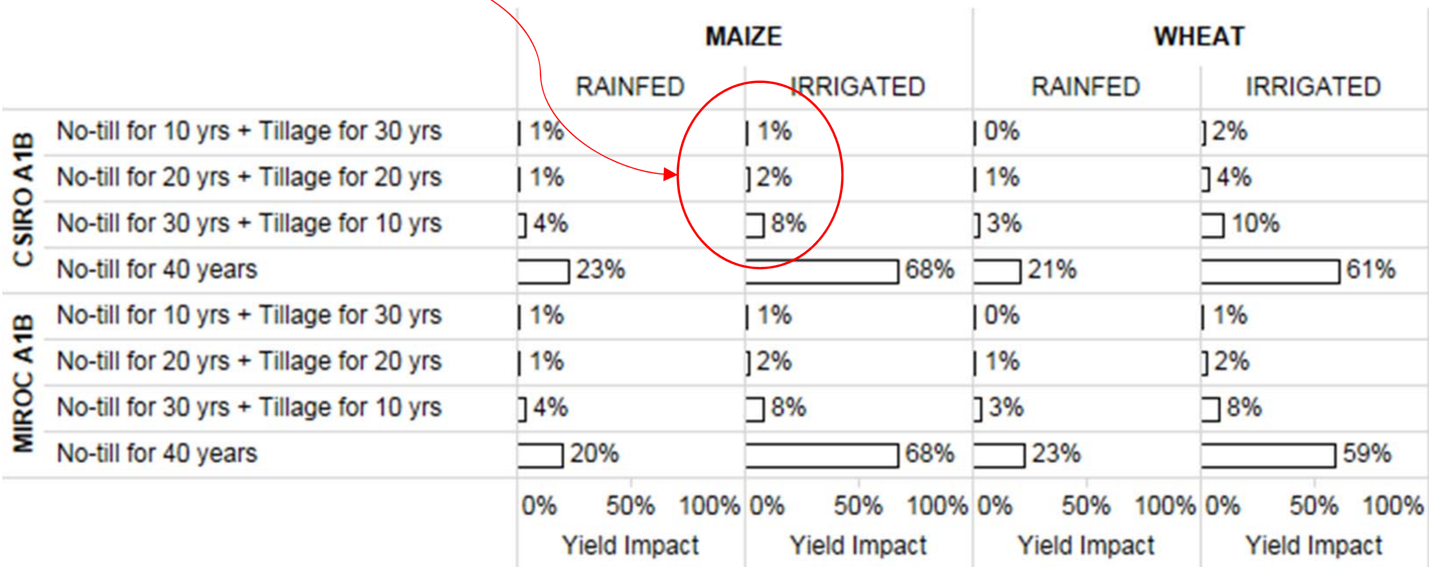


Source: Rosegrant et al. 2014.

No-Till: Long-term management is essential

- We assume farmers continue practicing no-till for 40 years; yield impact is calculated for the end period (years from 31 to 40)
- What if farmers stop practicing no-till?

Dramatically smaller impact



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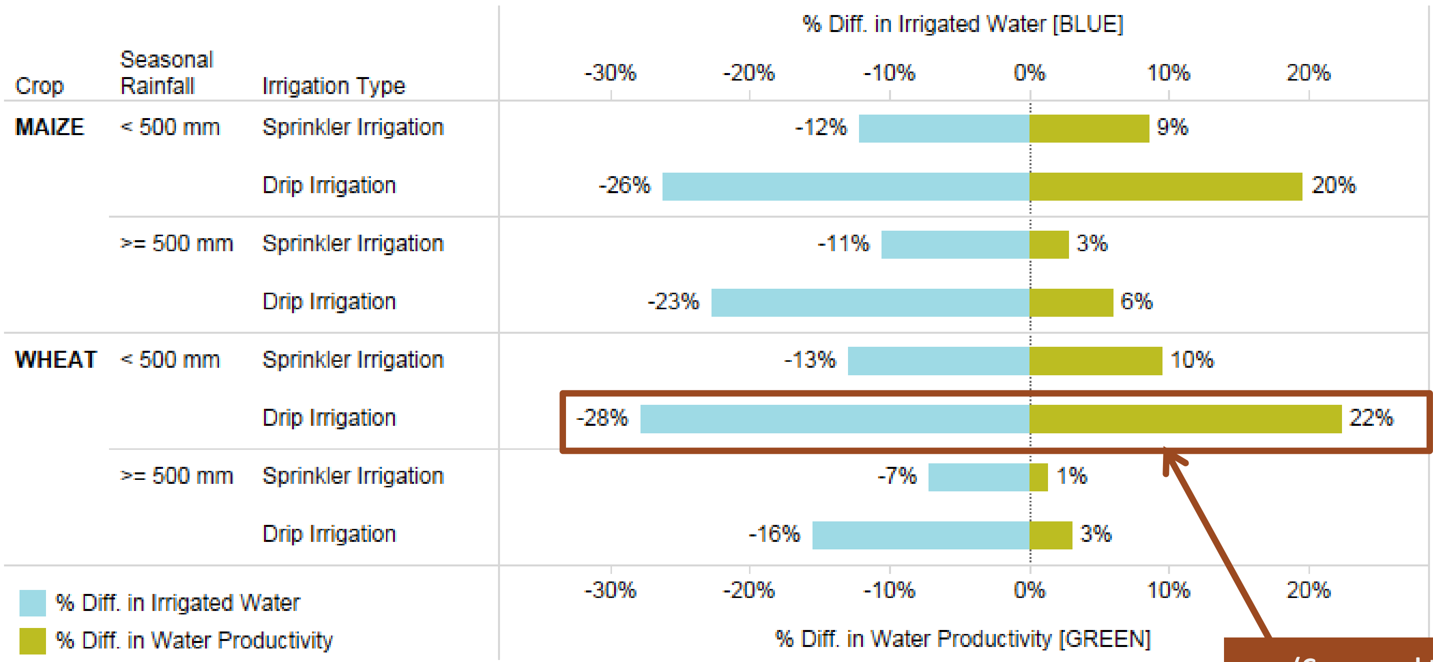
Efficient Use of Resources:

*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.

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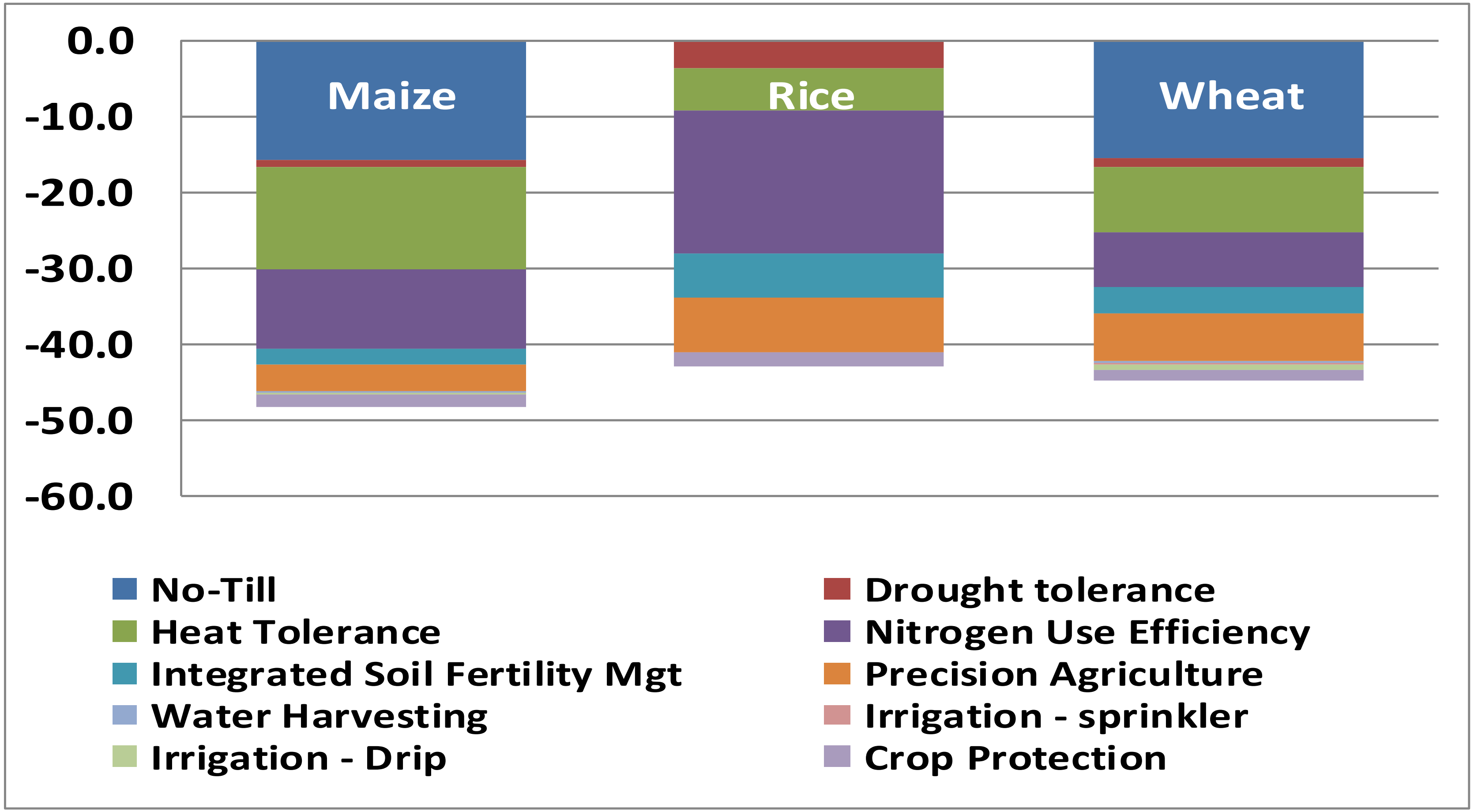
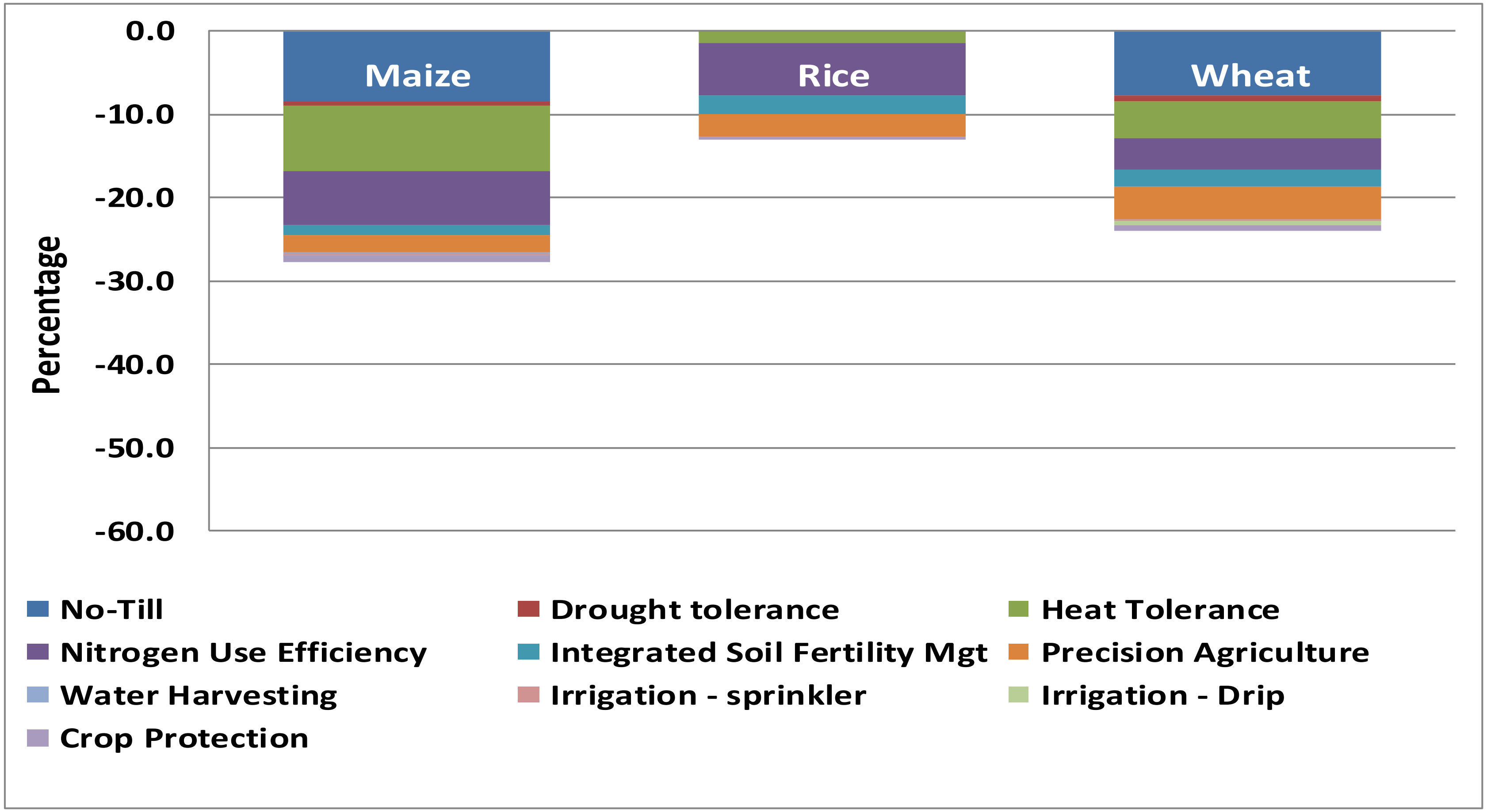
Price Effects of Technologies, 2050, compared to Baseline:

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.

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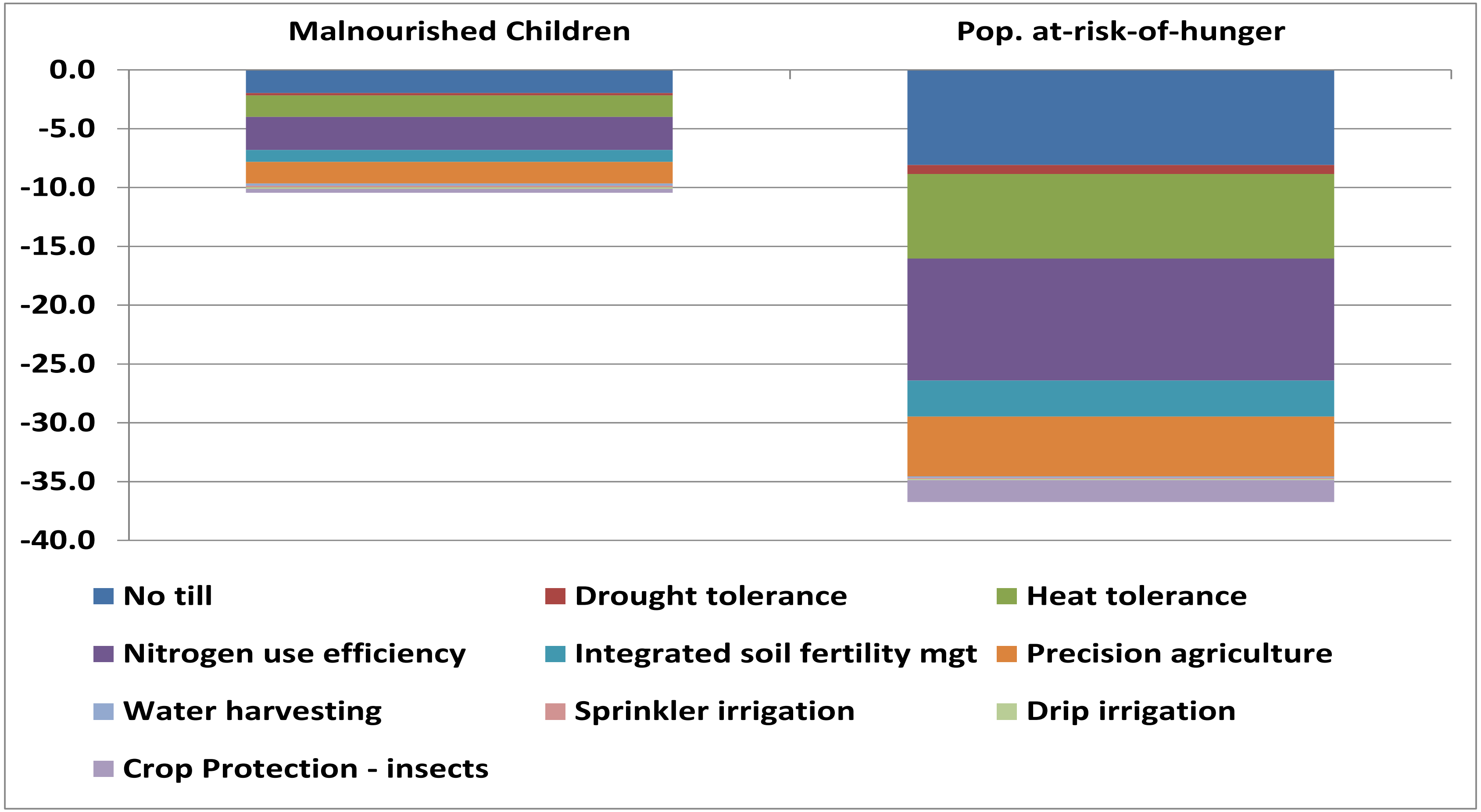
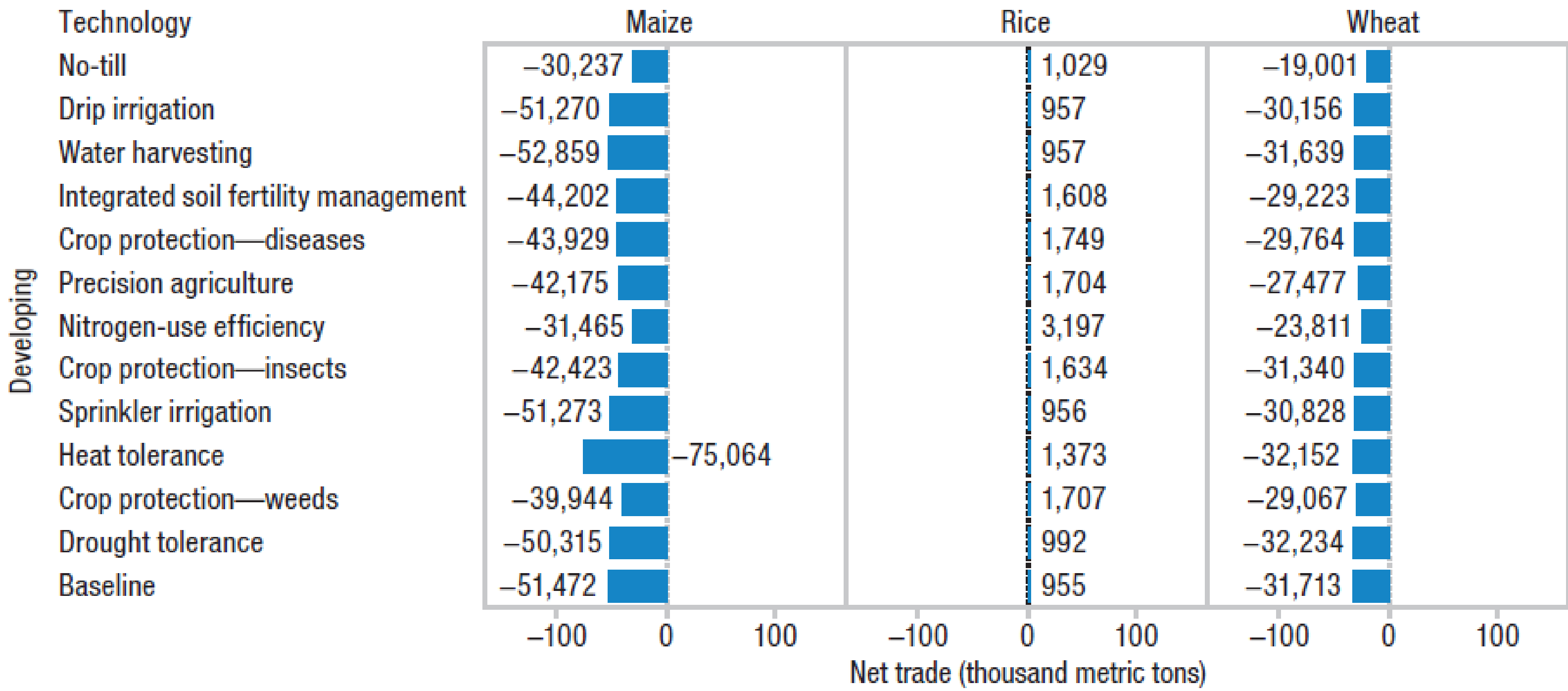
Food Security Effects of Technology relative to 2050 Baseline



Source: Rosegrant et al. 2014.

Net trade of maize, rice, and wheat for developing countries, by technology, 2050 (‘000 metric tons)



Note: Negative numbers = net imports. Positive numbers = net exports.

Source: Rosegrant et al. 2014

Improving Value Chains for Efficiency and Quality

- Four key investments to reduce post-harvest losses: electricity supply, paved roads, rail capacity, road capacity
- Overall cost to approximately halve PHL in developing countries = US$ 239 billion over the next 15 years
- Results in 10 percent reduction in hunger
- Investments also enable new technology potential: sensors revolutionizing value chains; development of cold chains
- Full tracking of food from source to final use; monitoring quality through the chain: reduction of food loss and waste with consequent improvement of food security

Rosegrant, Mark W.; Magalhaes, Eduardo; Valmonte-Santos, Rowena; and Mason-D'Croz, Daniel. 2018. Returns to investment in reducing postharvest food losses and increasing agricultural productivity growth. In Prioritizing development: A cost benefit analysis of the United Nations' sustainable development goals, ed. Bjorn Lomborg. Ch. 18 Pp. 322-338. Cambridge, U.K.: Cambridge University Press. https://doi.org/10.1017/9781108233767.020

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Constraints to Adoption of Advanced Technology in Developing Countries

Despite apparent profitability of some advanced technologies, limited adoption of practices at scale by producers in developing countries

- Constraints to adoption
  - Physical - soil, rainfall, temperature, drought, terrain
  - Economic - lack of credit or own resources for inputs, low income, poor terms of trade
  - Risk aversion - high discount rates due to poverty, lack of risk-spreading mechanisms
  - Social – gender (lack of assets)
  - Environmental - climate change, pests and pathogens, dust storms
  - Institutional - land tenure, access to markets, extension services

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Realizing the opportunities of advances in the biological sciences and navigating evolving policy and regulatory landscapes

- **Challenge**
  - Gene editing, synthetic biology, and other applications hold great potential for enhancing agricultural productivity, food security, and resilience to climate change
  - However, policy and regulatory landscapes affect how these technologies are shared among countries and how their benefits are distributed among citizens
  - High cost of regulation has limited the access of public and small-scale developers and the reduced benefits of new gene-based technologies
- **Directions**
  - Gene editing that leads to the development of plants that could also have come into existence naturally or by conventional breeding techniques should not be classified as GMOs and should be regulated like conventionally bred crops
  - International investment in regional centers of excellence in genomics and plant breeding in developing countries, especially Africa

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Leveraging the value of remote sensing and big data

- Challenge
  - Remote sensing, localized sensors, and open datasets are increasingly becoming available across scales and disciplines from multiple sources
  - High potential, but few successful business models in developing world
- Directions
  - Broad area apps: monitoring water availability and flows through rivers and irrigation systems for real-time management
  - Farm-level apps: satellite and drone imagery, precise sensors linked to big data can optimize planting crop management (but can it work on small farms?)

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Examples of new directions in supporting technology adoption

- Analytical tools and big data that identify constraints to adoption and distribution of benefits from technical change
    - Ready-to-use ex ante assessment apps for technology developers
- Analytical tools that improve accounting for gender, institutions, and rights in technical and social change processes
    - Field-based apps for implementation partners working with communities
    - Targeting technologies, practices, and incentives based on gender roles and responsibilities (seeking to break down differential access to assets, information, technologies for women)

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Examples of new directions in supporting technology adoption

- Applications that combine technology with financial and information services to accelerate technical change
  - Stress-tolerant cultivar promotions tied to insurance and IT-assisted monitoring products
- Regulatory designs that improve incentives from innovation, development, deployment and husbandry of new climate-resilient technologies throughout the value chain

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Policies for Sustainable Agricultural Technologies

- Crop breeding targeting yield increases, input efficiency, and abiotic and biotic stresses
- Enabling conditions: strengthen land and water rights; remove general subsidies and sharply target financial, insurance, or input subsidies for new technology adoption
- Rural infrastructure investment to improve access to markets, risk insurance, credit, inputs (roads, mobile phone towers)
- Regulatory reform: Reduce hurdles to approval and release of new cultivars and technologies
    - Remove impediments to adoption (lumping of gene editing with GMOs, excessive testing and certification requirements, foreign investment barriers, ad hoc biosafety decision-making)

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