Global Perspectives on Food Security and Environmental Sustainability

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Outline

- Global Challenges for Food Security and Environmental Sustainability
- Global Food Security and Sustainability Scenarios
- Regional Assessment for Latin America and the Caribbean
- Policies for Sustainable Agricultural Productivity Growth

GLOBAL CHALLENGES FOR FOOD SECURITY AND ENVIRONMENTAL SUSTAINABILITY

Global Challenges for Food Security and Environmental Sustainability

- Increasing population and demographic shifts
- Rising incomes and demand and diet changes
- Economic growth and meat consumption
- Rising oil prices / biofuel expansion
- High and volatile food prices
- Limited land resources
- Depletion of groundwater, water pollution, declining water quality, and degradation of water-related ecosystems
- Climate change

Two Critical Issues

1. Unsustainable intensification, mainly in higher potential or irrigated areas

   – Surface and groundwater depletion due to excessive irrigation - *Aral Sea crisis*

   – Salinization in poorly drained irrigated lands - *South and Central Asia*

   – Waterlogging, soil compaction and soil toxicity in continuous paddy production - *Southeast Asia*

   – Water pollution, adverse health effects, pest outbreaks caused by excessive agro-chemical use in intensive systems - *Asia and Latin America*

   – Soil erosion due to excessive tillage on steeply sloping lands - *East African highlands, Southeast Asian uplands, Central American hillsides, others*

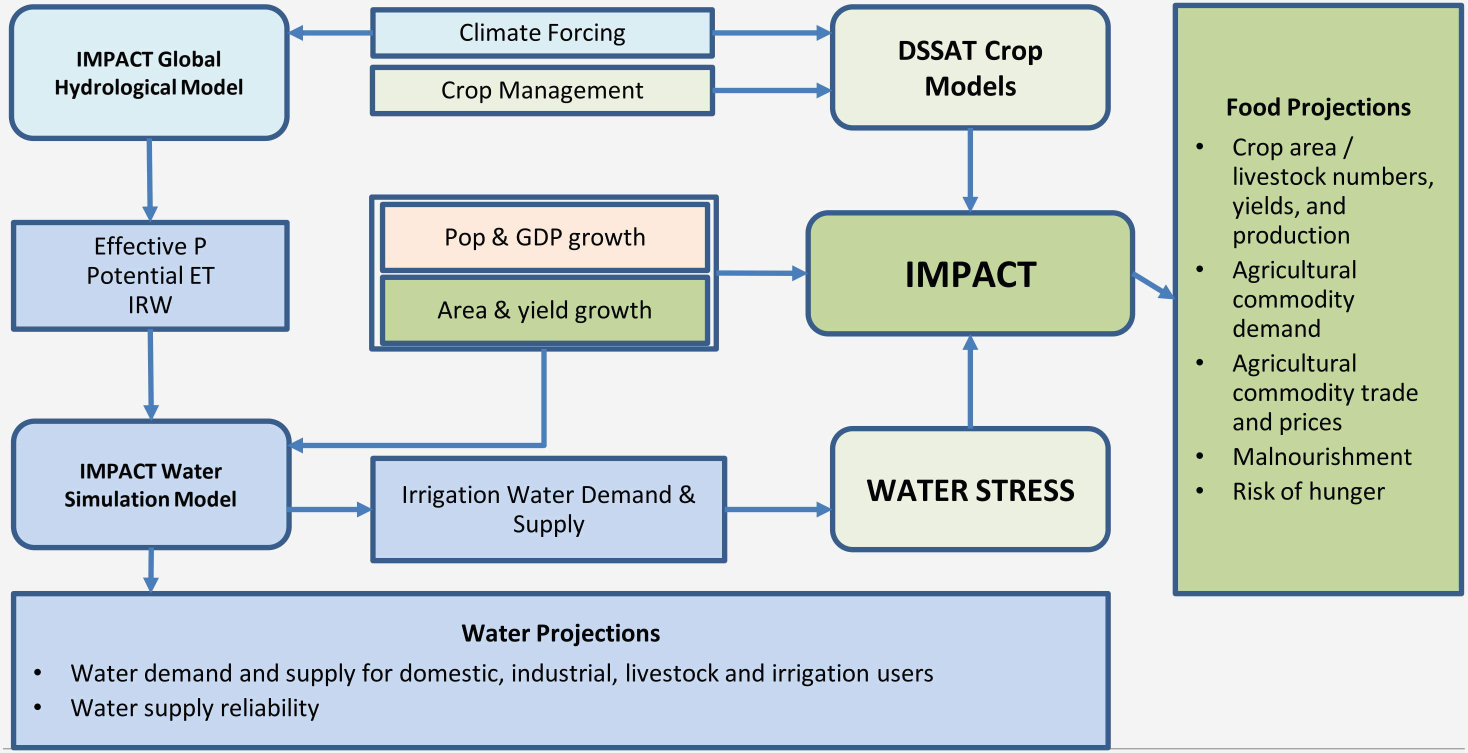
Two Critical Issues

2. Unsustainable “non-intensification” (or partial intensification), mainly in less favored areas
   - Soil fertility depletion in Sub-Saharan Africa due to
     - declining fallow
     - inadequate application of soil nutrients
   - Deforestation and conversion of rangelands to cropping in all continents due to
     - extensification of crop production
   - Overgrazing of remaining rangelands in Africa and Asia due to
     - continued dependence on extensive grazing
     - declining rangelands, rapid growth in meat demand

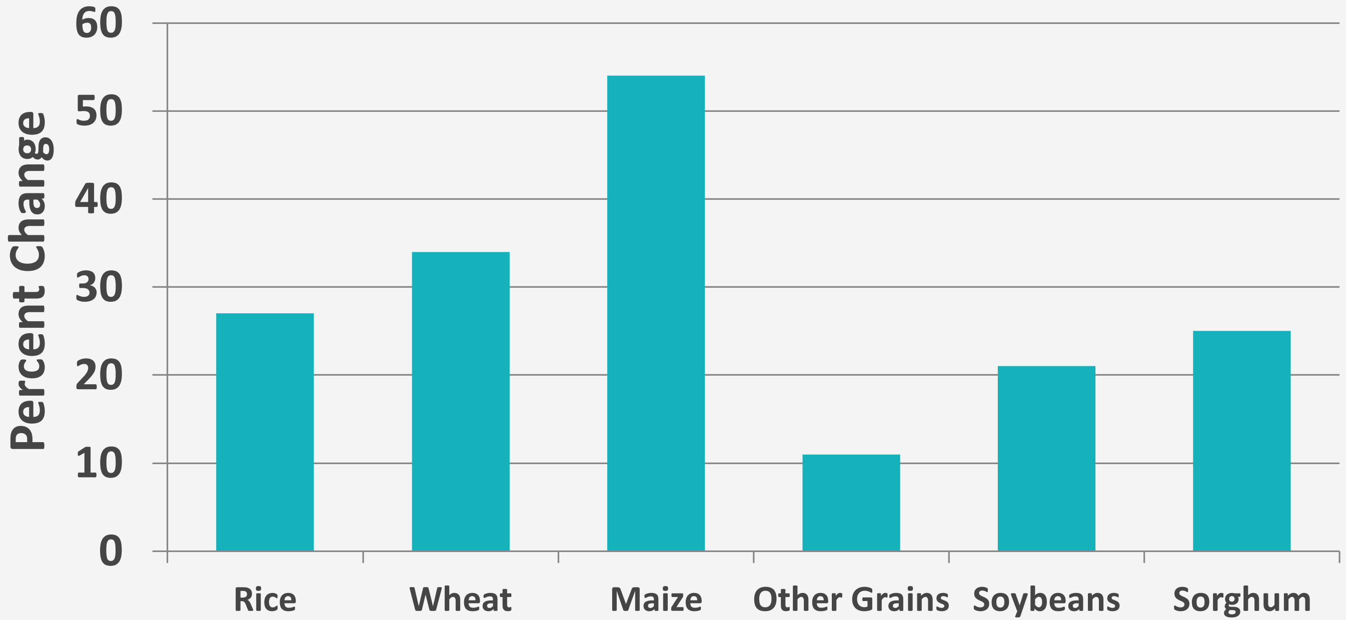
GLOBAL FOOD SECURITY AND SUSTAINABILITY SCENARIOS

The IMPACT3 Modeling Suite

Linked system of hydrological, water use, crop simulation, and partial equilibrium economic models

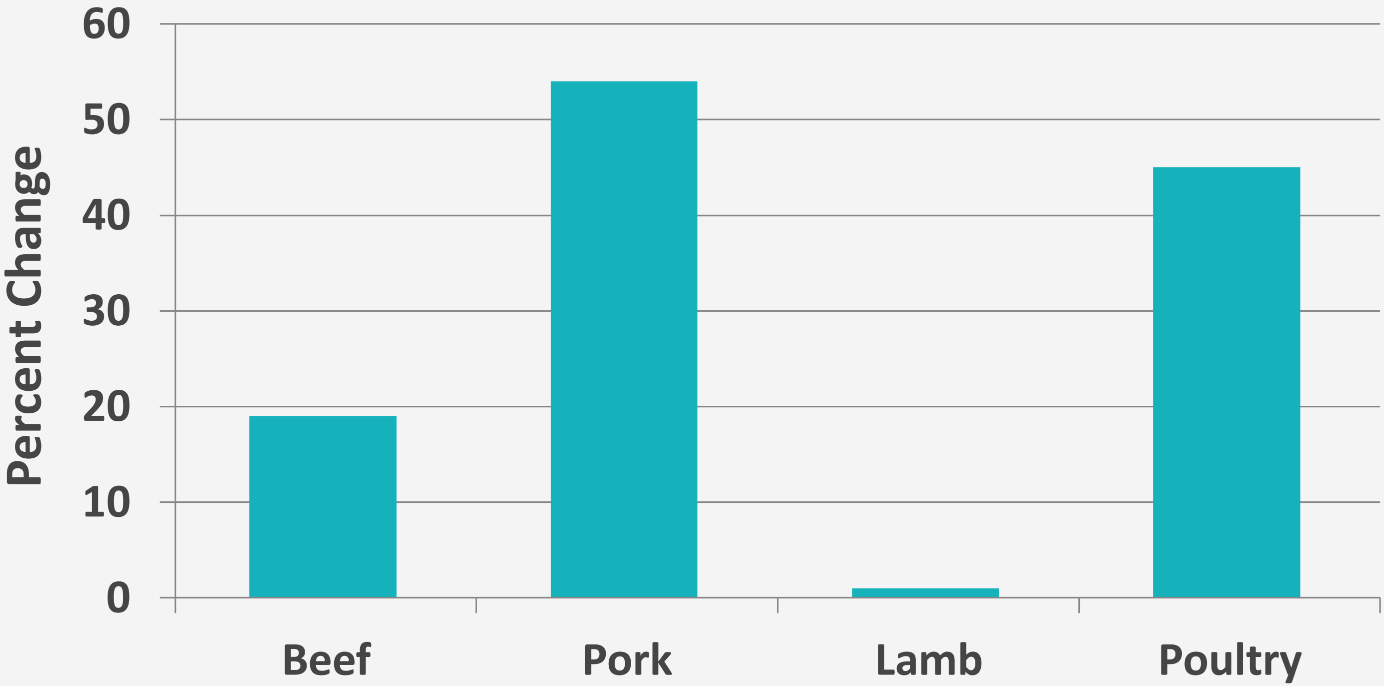


Percent Change in World Prices of Cereals between 2010 and 2050



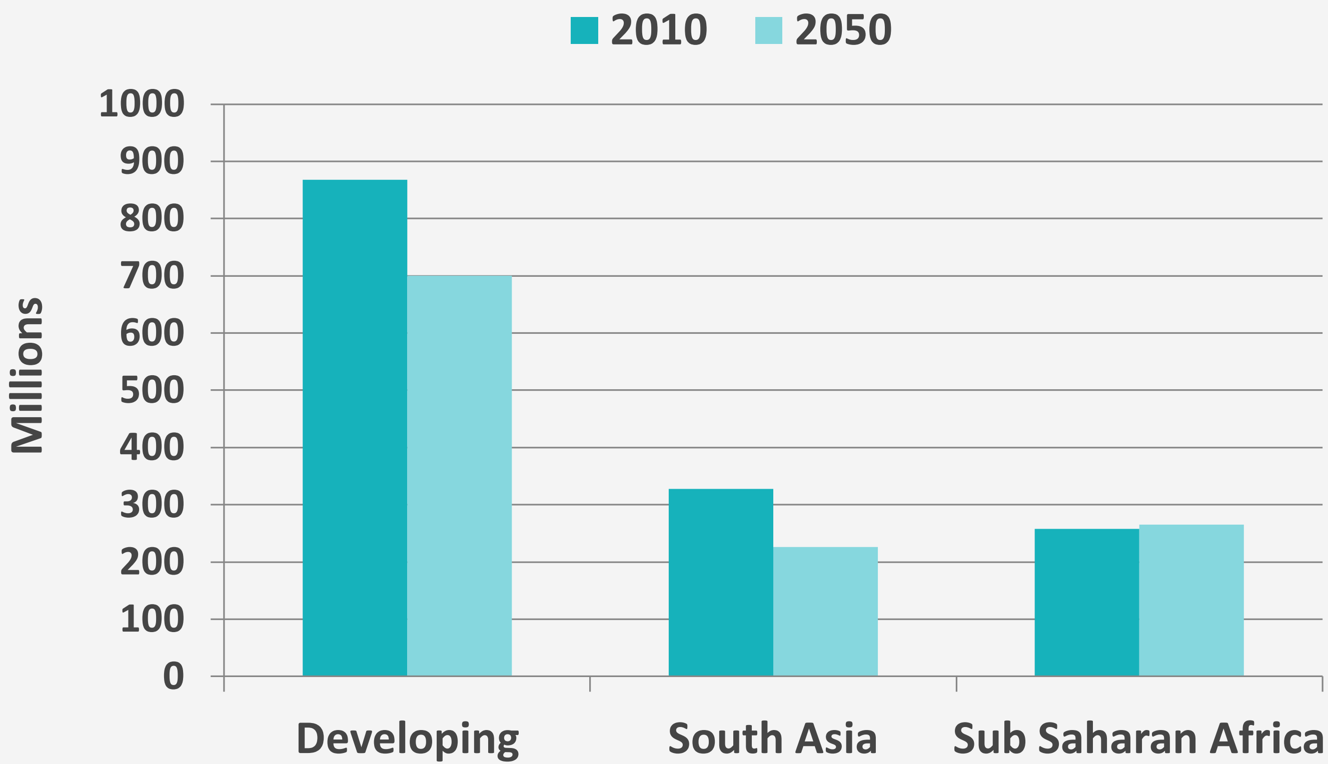
Source: Rosegrant, M.W., S. Tokgoz, and P. Bhandary. 2013. The New Normal? A tighter global agricultural supply and demand relation and its implications for food security. American Journal of Agricultural Economics 95(2)303-309. http://ajae.oxfordjournals.org/content/95/2/303

Percent Change in World Prices of Meat between 2010 and 2050



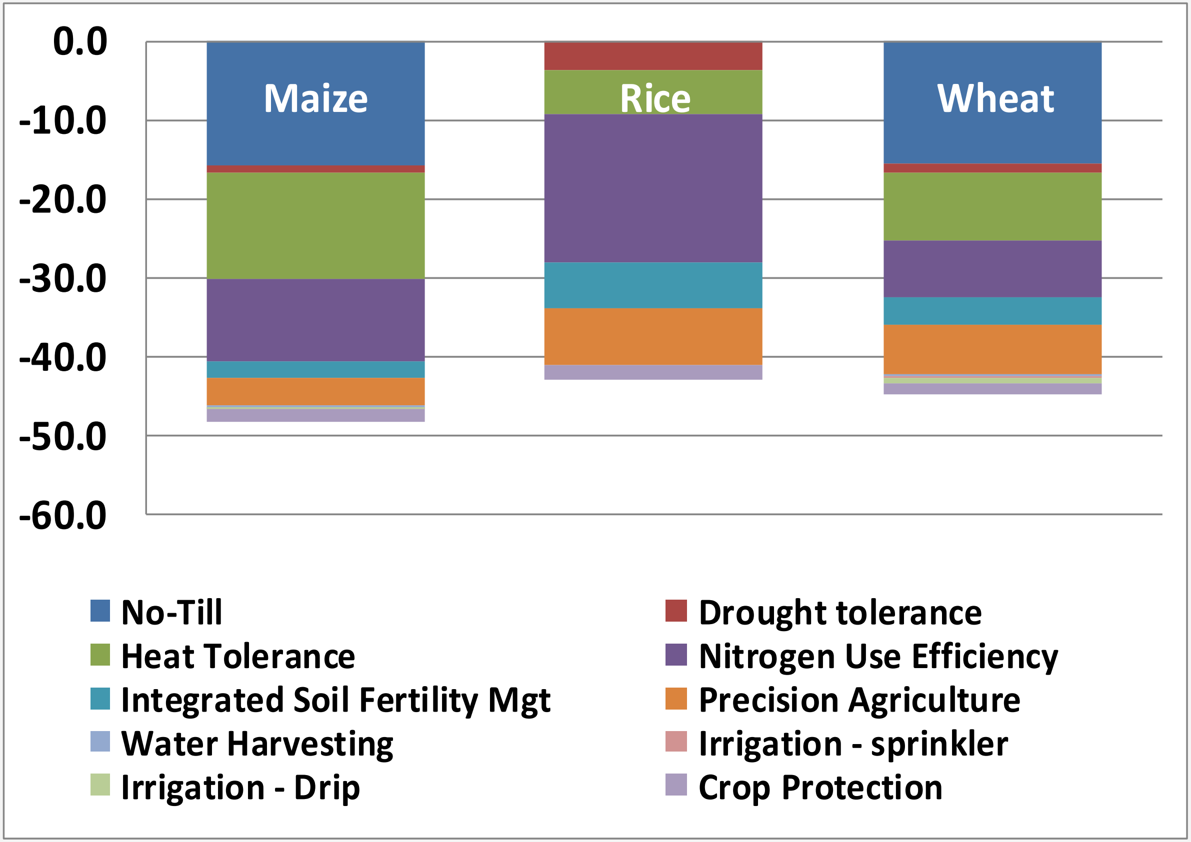
Source: Rosegrant, Tokgoz and Bhandary, 2013

Population at the Risk of Hunger



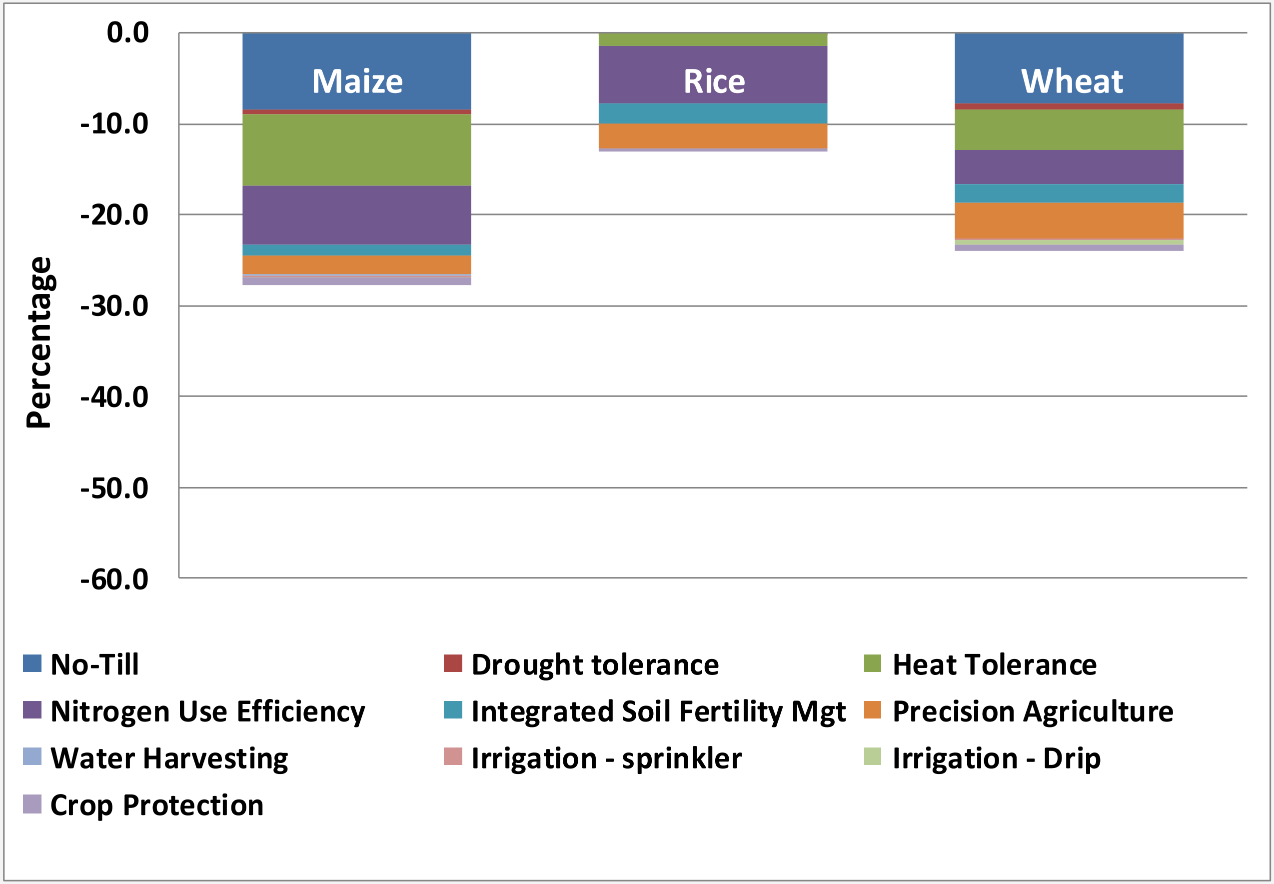
Source: Rosegrant, Tokgoz and Bhandary, 2013

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



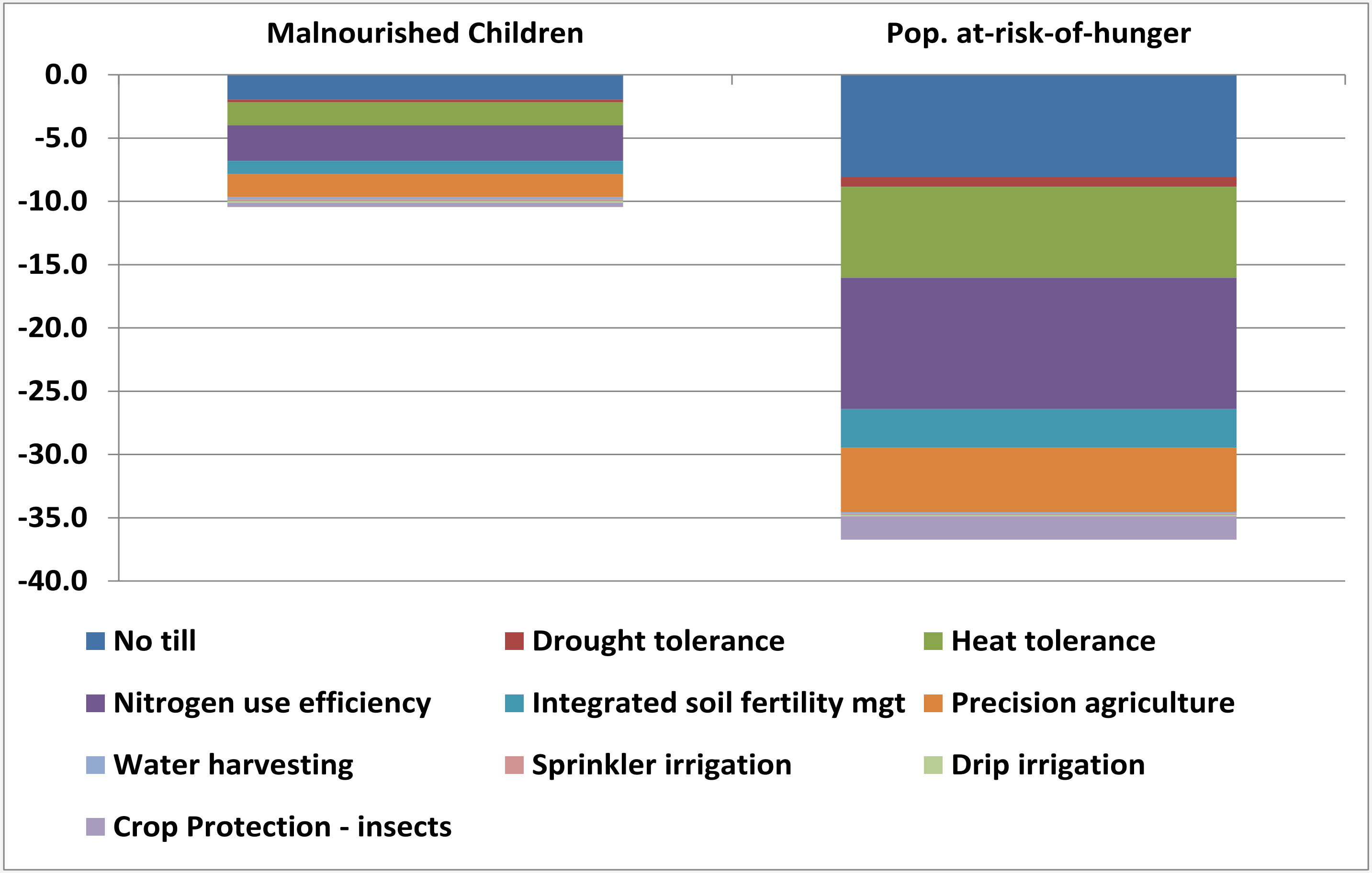
Source: Rosegrant, Mark W.; Koo, Jawoo; Cenacchi, Nicola; Ringler, Claudia; Robertson, Richard D.; Fisher, Myles; Cox, Cindy M.; Garrett, Karen; Perez, Nicostrato D. and Sabbagh, Pascale. 2014. Food security in a world of natural resource scarcity: The role of agricultural technologies. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://www.ifpri.org/sites/default/files/publications/oc76.pdf

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



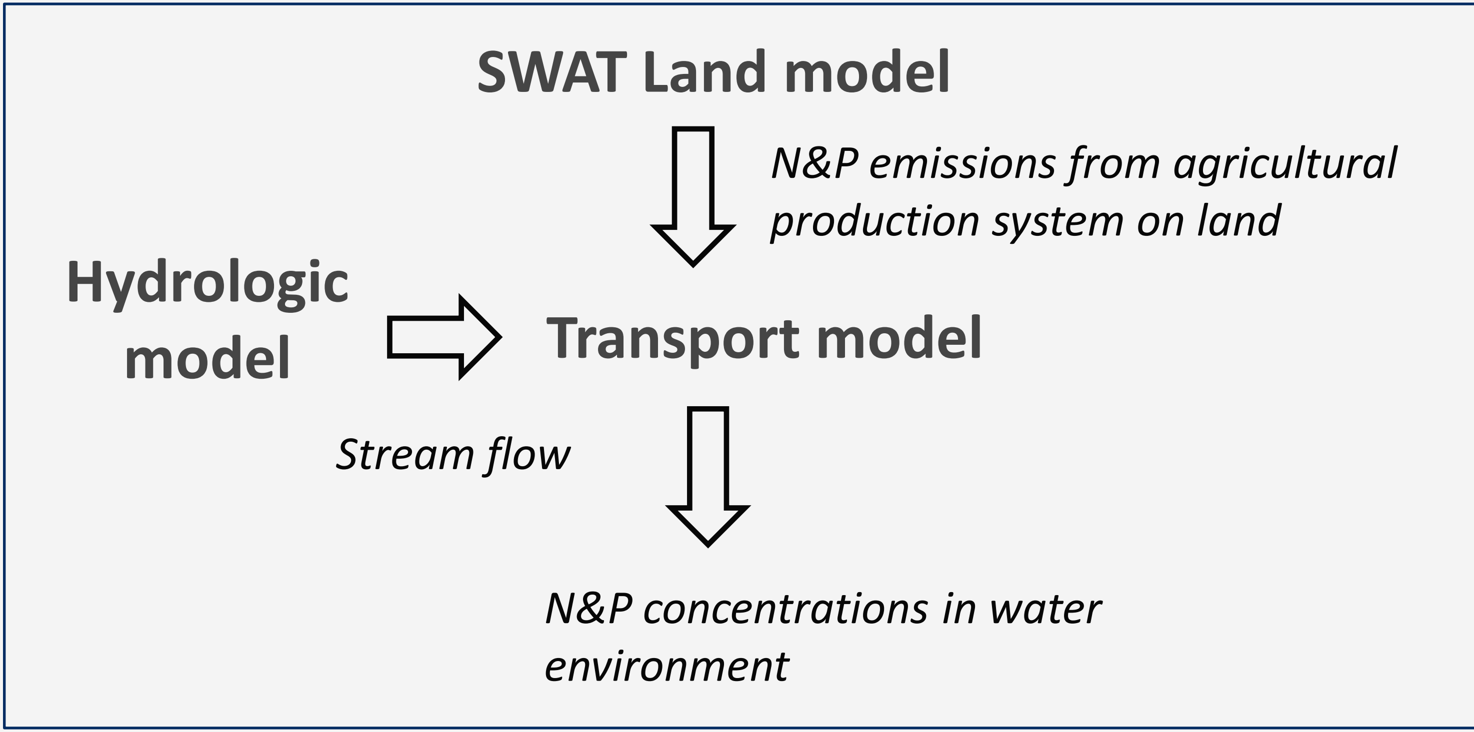
Source: Rosegrant et al. 2014.

Food Security Effects of Technology relative to 2050 Baseline



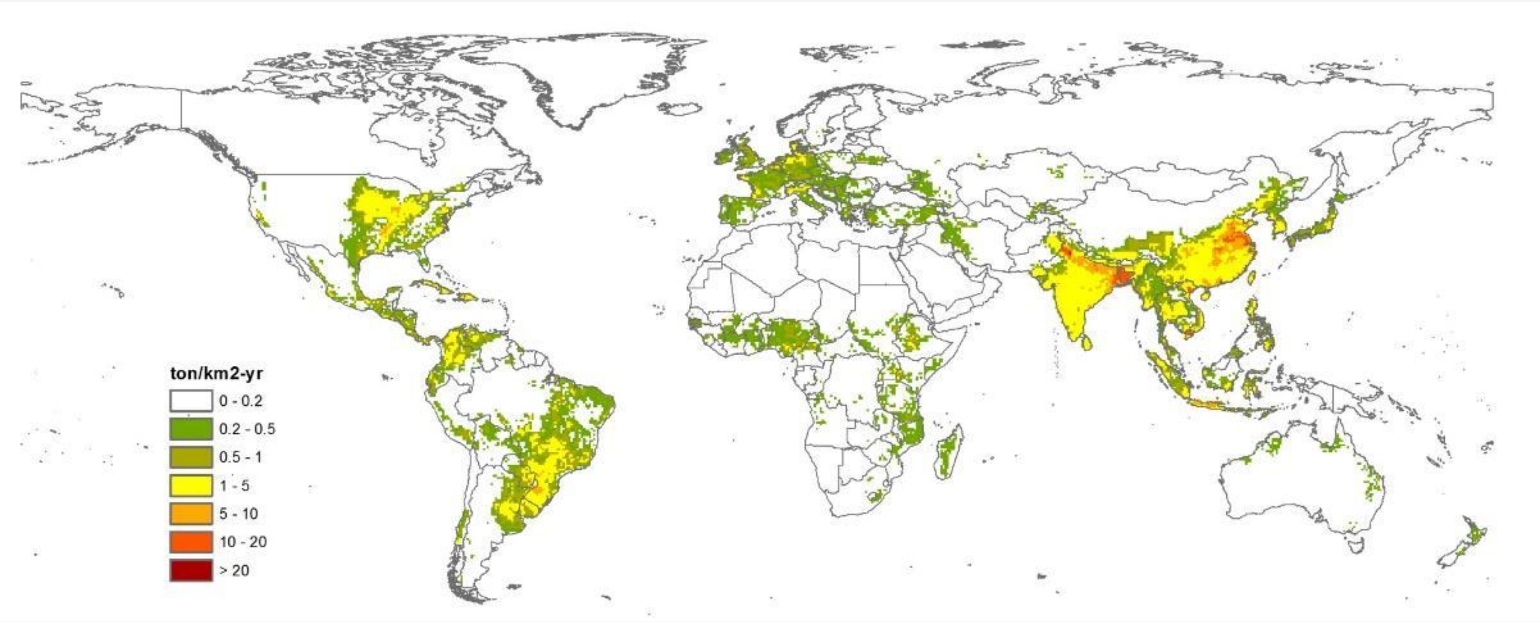
Source: Rosegrant et al. 2014

Global Water Quality Assessment



Source: IFPRI and Veolia. 2015. The murky future of global water quality. White Paper. IFPRI and Veolia.
https://www.veolianorthamerica.com/sites/g/files/dvc596/f/assets/documents/2015/04/IFPRI_Veolia_H2OQual_WP.pdf

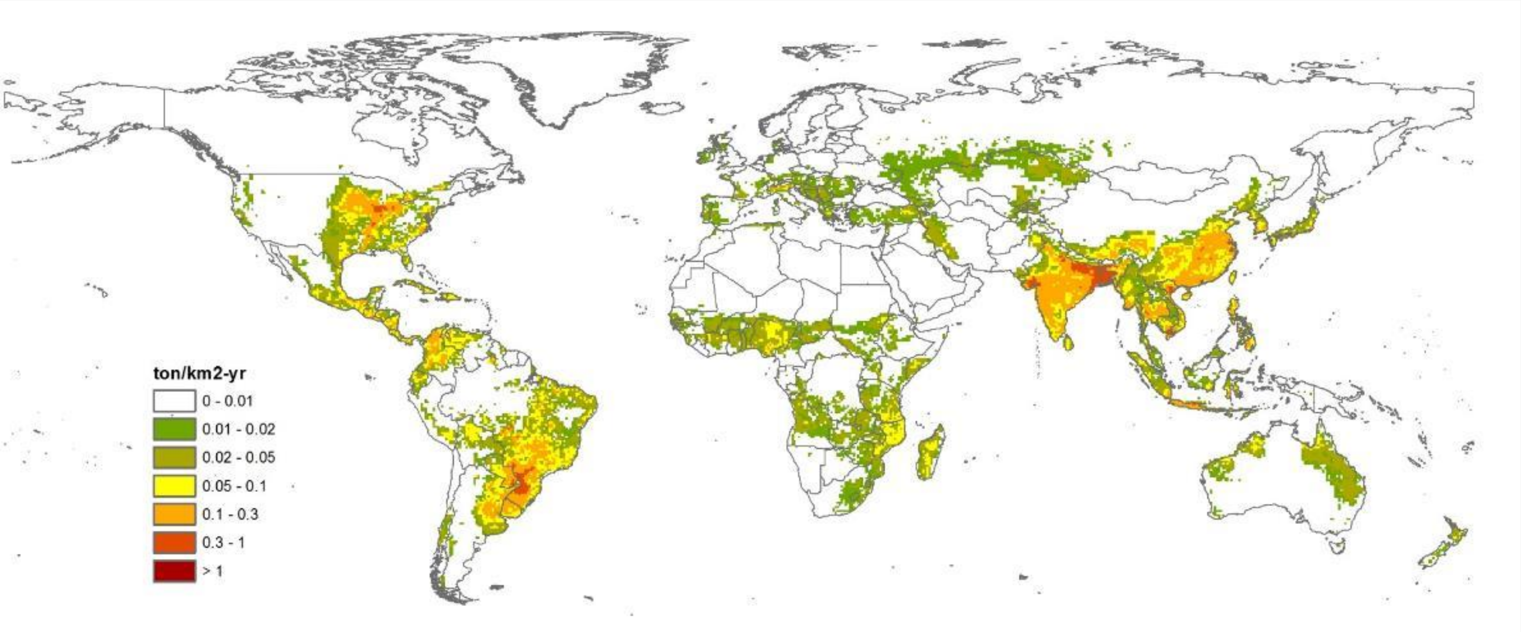
Nitrogen Loading-base Period



46 million tons/yr

Source: IFPRI and Veolia 2015

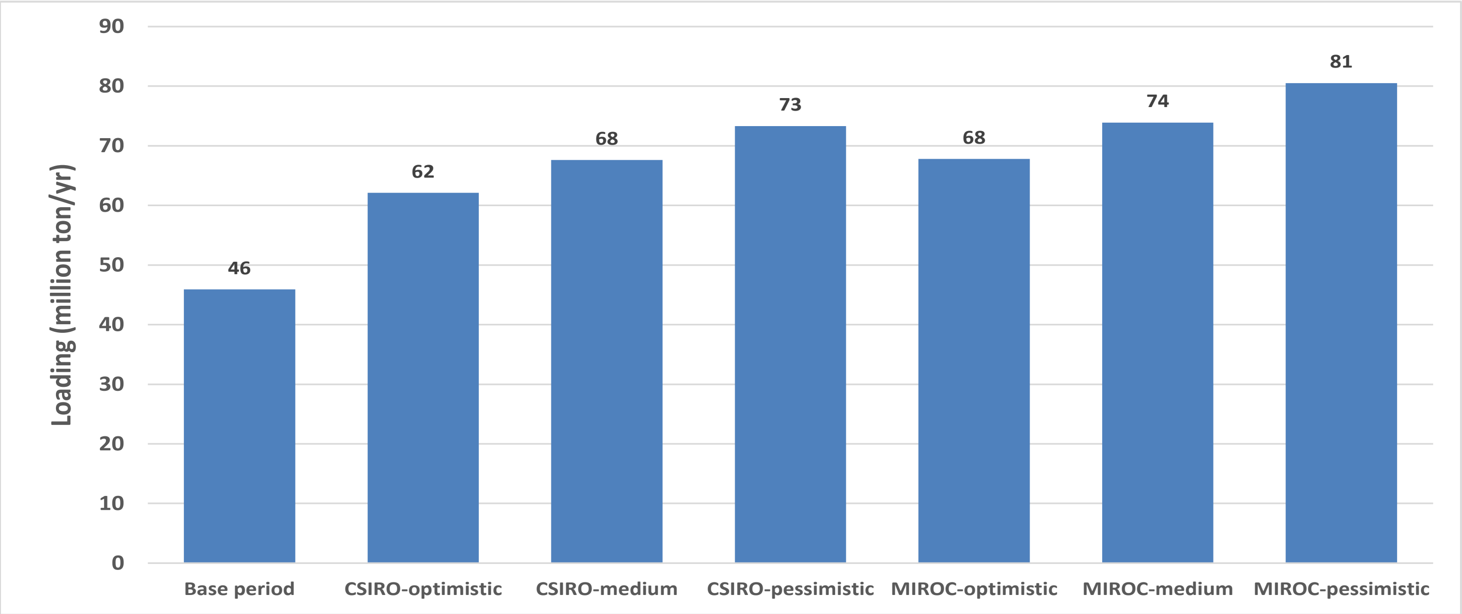
Phosphorus Loading-base Period



2.7 million tons/yr

Source: IFPRI and Veolia 2015

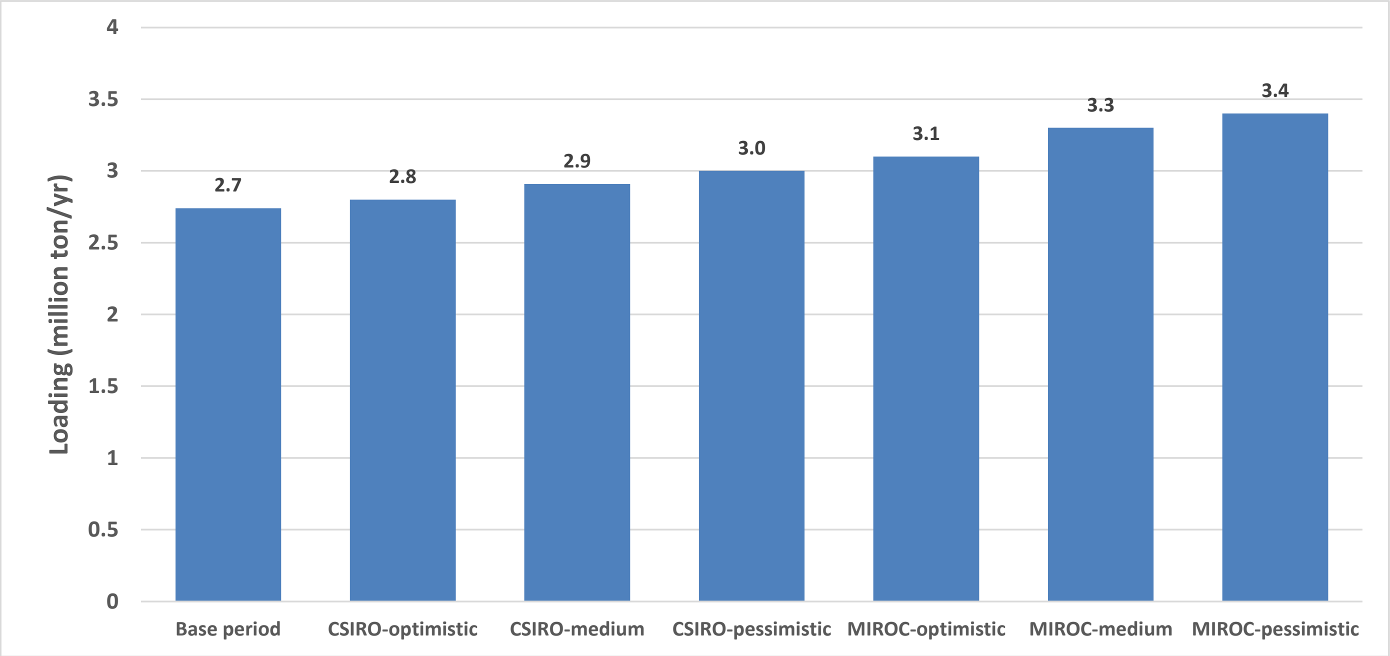
Nitrogen Loading from Agricultural Sources – 2000-2005 Base Period and 2050 Projections



Optimistic scenario: 40% NUE improvement; Medium scenario: 20% NUE improvement; Pessimistic scenario: no NUE improvement

Source: IFPRI and Veolia 2015

Phosphorus Loading from Agricultural Sources – 2000-2005 Base Period and 2050 Projections



Optimistic scenario: 40% NUE improvement; Medium scenario: 20% NUE improvement; Pessimistic scenario: no NUE improvement

Source: IFPRI and Veolia 2015

REGIONAL ASSESSMENT FOR LATIN AMERICA AND THE CARIBBEAN

Scenarios

- Five alternative agricultural development pathways compared to Business-As-Usual (BAU)
  - BAU (1) assumptions
    - Population growth: UN medium variant projections
    - Economic growth: TechnoGarden scenario of Millennium Ecosystem Assessment
    - Climate change: A1B scenario of IPCC-SRES
    - Agriculture growth rates: continuation of past trends in irrigated and rainfed area growth rates as well as crop and livestock productivity growth with a gradual slow down in growth
    - Trade policies: kept constant over time so no further trade liberalization
  - Alternative future scenarios
    - (1a) Global liberalized trade scenario;
    - (2) Latin America and Caribbean (LAC) intensification scenario;
    - (3) LAC sustainable intensification scenario;
    - (4) LAC closed yield gaps scenario; and
    - (5) LAC extensification scenario.

Scenarios

- Distinct features of each scenario summarized in next slide
- Numbers should be interpreted as deviation from BAU
- Selection of parameters - Due to high agricultural specialization in LAC, focus of analysis include:
  - Food crops that together accounted for more than 70% of agricultural production in 2010: maize, rice, wheat, soybeans, sugarcane, potatoes and sorghum
  - Livestock products: cows, sheep, goats, pigs and chickens
  - Pasture land estimations: cows, sheep and goats
- All alternative scenarios assume phased 40% reduction in trade distortions by 2050. In the trade lib scenario this is the only difference from BAU

Alternative Future Scenarios for 2010-2050 Compared to BAU

Parameters	(2) Intensifi-cation	(3) Sustainable Intensification		(4) Closing Yield Gaps	(5) Extensification
		Higher NUE (a)	Precision Agri (b)		
Livestock, LAC (growth)					
- Number	nc	nc	nc	nc	+30%
- Yield growth	+30%	+30%	+30%	+30%	-30%
Seven food crops*, LAC (growth)					
- Yield growth changes	+60%	+60%	+60%	Closed yield gaps, region and crop specific (gradually until 2050)	-60%
- Irrigated area growth	+25%	+25%	+25%	+25%	-25%
- Rainfed area growth	Zero exogenous area growth	Zero exogenous area growth	Zero exogenous area growth	Zero exogenous area growth	+15%

Notes: * Applied to maize, rice, wheat, soybeans, sugarcane, potatoes, sorghum; LAC - changes are applied to Latin America and the Caribbean

Alternative Future Scenarios for 2010-2050 Compared to BAU

Parameters	(3) Sustainable Intensification	
	Higher NUE (a)	**Precision Agriculture (b)**
Basin efficiency (ratio between 0 to 1)	+15%-points (gradually until 2050)	+15%-points (gradually until 2050)
Increased NUE*	Increased NUE by 20% (LAC, in 2050)	nc
Precision agriculture*	nc	Optimized nitrogen use (LAC, in 2050)

Environmental Trade-Offs of Future Food Production Pathways. PLOS ONE 10 (1): 1-24

Notes: nc - no change compared BAU assumptions; * applied to maize, rice, wheat, soybeans, sugarcane, potatoes, sorghum; LAC - changes are applied to Latin America and the Caribbean; Globally - changes compared to BAU are applied globally

Water Quality Assessment Methods

- Impacts of expanded or intensified agricultural activity on water quality assessed by quantifying variations of nitrogen-based pollutants over time under each scenario considered; involves linking IMPACT results to Soil and Water Assessment Tool (SWAT)
- SWAT model parameterize on a 0.5 by 0.5 degree longitude-latitude grid to estimate annual rates of agricultural nitrogen (N)-emissions (including crop and pasture land emissions)
- **Two sustainable intensification scenarios (3a/3b) were constructed**
  - Sustainable intensification scenario with nitrogen-use efficiency (NUE) improvement (3a) - input rates of fertilizer and manure nitrogen on crop land adjusted to simulate NUE enhancement by +20%
  - To represent precision agriculture techniques in sustainable intensification scenario (3b), SWAT model optimized the quantity and timing of nitrogen fertilizer/manure applications, given nitrogen requirements of the major crops

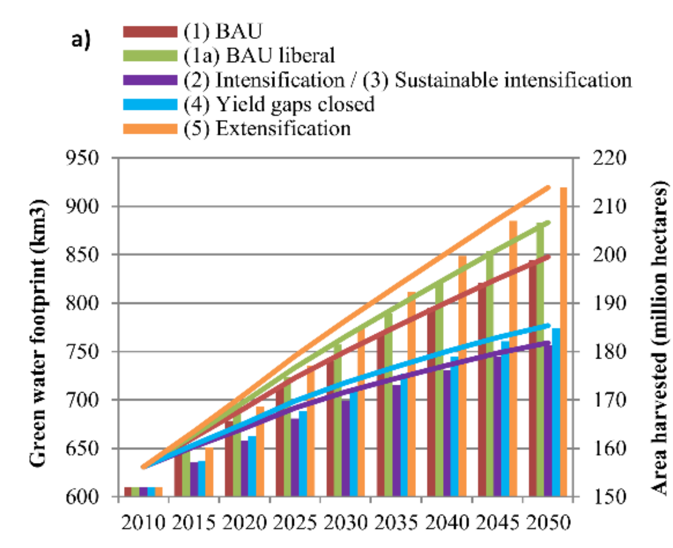
Carbon Assessment

- Impacts on carbon (C) stock losses linked to projected expansion of cropland and pasture areas due to livestock production quantified in LAC for each of agricultural production scenarios between 2010 and 2050
- For livestock production, assumption is that all future pasture expansion will expand over former natural vegetation

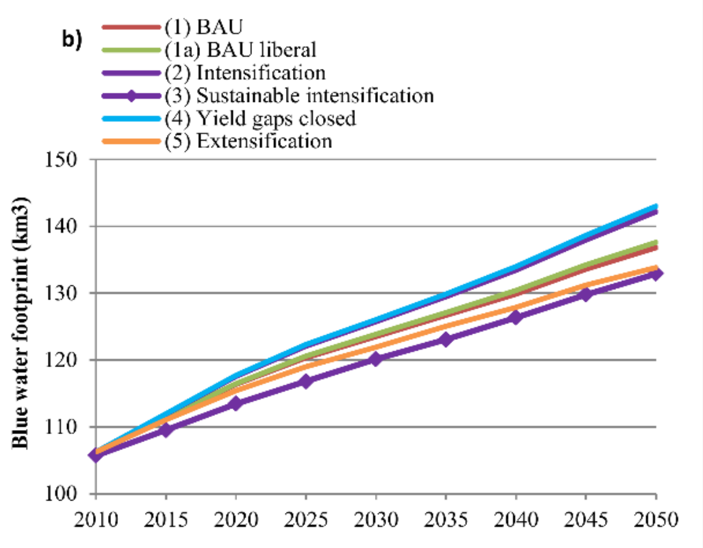
Biodiversity Assessment

- Application of species-area relationships to account for potential biodiversity trade-offs associated with each scenario of agricultural production in LAC
- Countryside model was used to predict changes in endemic bird's risk of extinction and endangerment (expressed as an index in %) associated with projected increase in cropland and pasture area between 2010 and 2050
- To assess the bird's risk of extinction and endangerment by FPU and under different scenarios, the following were estimated:
  - i. actual number of birds and the percentage of threatened species by FPU;
  - ii. area of main land uses per FPU (natural vegetation, pastures, cropland, urban/artificial); and
  - iii. linear relationship between the percentage of threatened species and habitat availability and suitability

Green and Blue Water Footprints under Different Scenarios in Latin America and the Caribbean (LAC), 2010-2050



(a) Evolution of total Green Water Footprint (line chart on left axis) and area harvested (bar chart on right axis) of all crops in LAC, 2010-2050

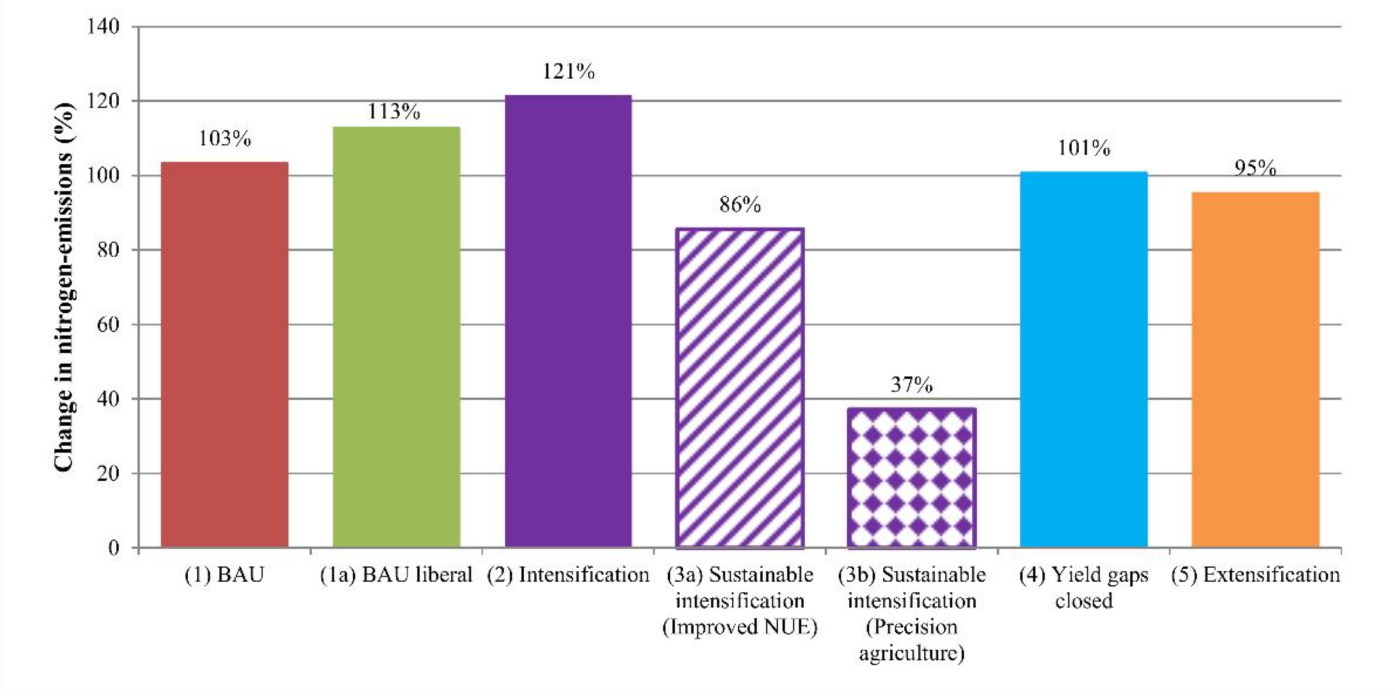


(b) Evolution of total Blue Water Footprint of all crops and livestock in LAC, 2010-2050

Source: Flachsbarth, et al. 2015.

- Green water footprint - rainwater evaporated or incorporated into a specific crop by FPU
- Blue water footprint - volume of surface or groundwater evaporated or incorporated into a specific crop or livestock in an FPU
- For green water, the Intensification (2) and Sustainable Intensification (3) scenarios presented together due to same productivity assumptions and differ in blue water use

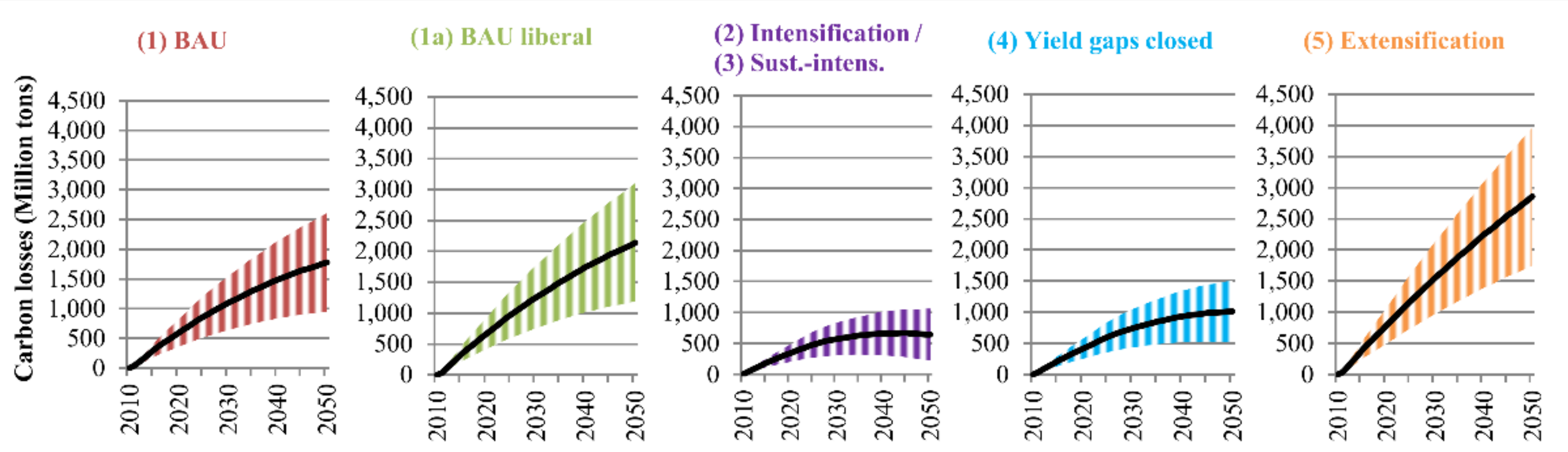
Changes (%) in Nitrogen-emission Rates in LAC between 2000 (Base Year) and 2050



Nitrogen-emission – discharge of particulate and dissolved nitrogen-based pollutants from land to water environments

Source: Flachsbarth, et al. 2015.

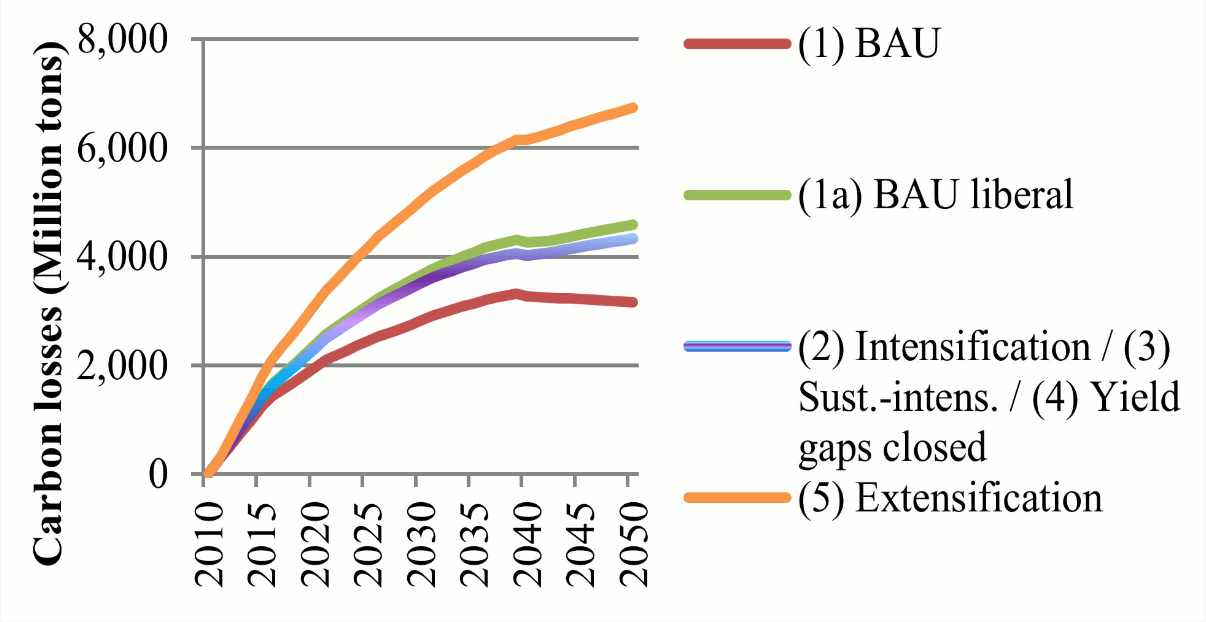
Annual Net Changes in Carbon Stock Losses due to Crop Production under Different Scenarios in LAC, 2010–2050



Source: Flachsbarth, et al. 2015.

- Carbon (C) stock losses – linked to cropland expansion
- Values represent C stock losses from additional land conversion occurring in each year between 2010 and 2050
- Shaded area illustrates C storage losses between a defined lower and upper bound due to different land expansion pathways
  - Lower bound - C storage losses if 100% of crop land expands over existing pasture land
  - Upper bound - C storage losses if 100% of crop land expands over natural vegetation
  - Line illustrates mean of lower and upper bounds
- Intensification (2) and Sustainable Intensification (3) scenarios presented together due to same productivity assumptions and differ in water consumption and N-emissions

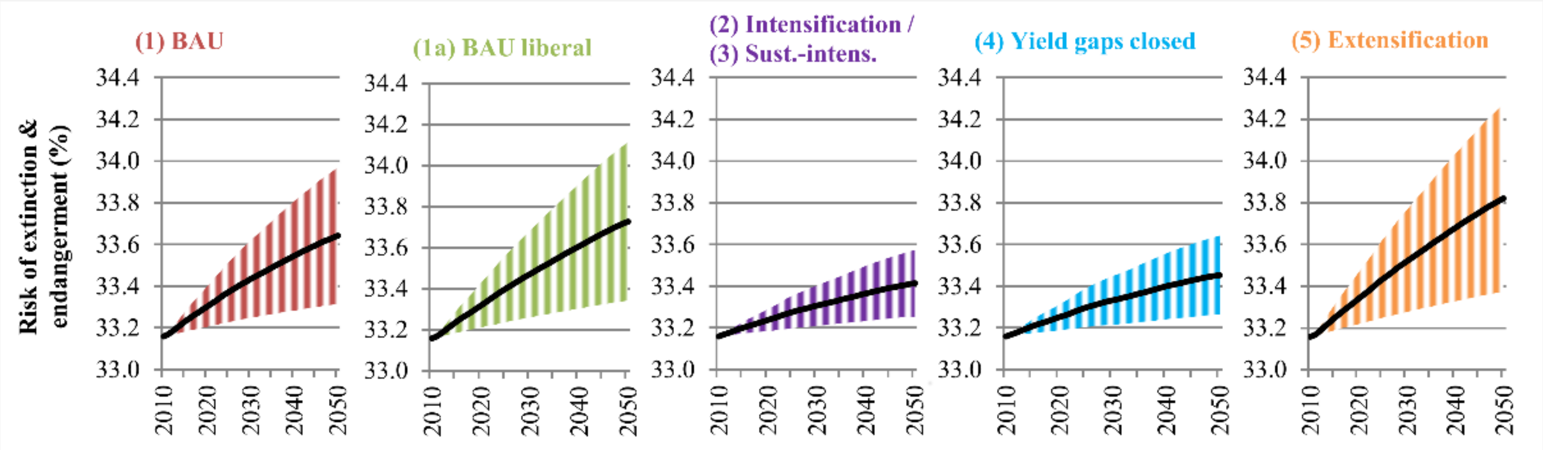
Annual Net Changes in Carbon Stock Losses due to Livestock Production under Different Scenarios in LAC, 2010–2050



Source: Flachsbarth, et al. 2015.

- Values represent carbon stock losses from additional land conversion occurring in each year between 2010 and 2050
- Intensification (2) and Sustainable Intensification (3) scenarios presented together due to same productivity assumptions and differ in water consumption and N-emissions

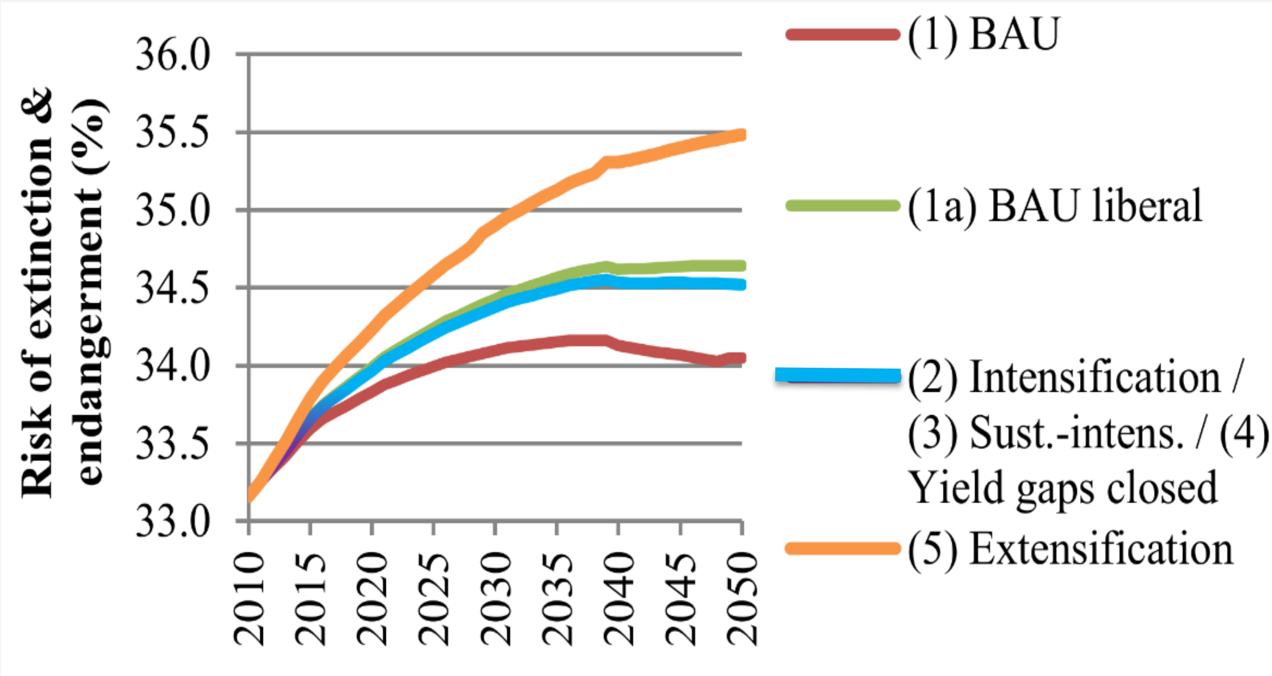
Annual Species Risk of Extinction and Endangerment due to Crop Production under Different Scenarios in LAC, 2010–2050



Source: Flachsbarth, et al. 2015.

- Risk expressed as an index in %; measure of the potential for a species to be threatened
- Shaded area - risk of biodiversity loss being between a defined lower and upper bound due to different land expansion pathways
  - Lower bound - risk of biodiversity loss if 100% of crop land expands over existing pasture land
  - Upper bound - risk of biodiversity loss if 100% of crop land expands over natural vegetation
  - Line - mean of the lower and upper bound
- Intensification (2) and Sustainable Intensification (3) scenarios presented together due to same productivity assumptions and differ in water consumption and N-emissions

Annual Species Risk of Extinction and Endangerment due to Livestock Production under Different Scenarios In LAC, 2010–2050



Source: Flachsbarth, et al. 2015.

- Risk is expressed as an index in %
- Intensification (2) and Sustainable Intensification (3) scenarios are presented together due to same productivity assumptions and differ in water consumption and N-emissions

POLICIES FOR SUSTAINABLE AGRICULTURAL PRODUCTIVITY GROWTH

Policy-induced Negative Consequences and Recommendations for Reform

- Water and irrigation policy
  - — Drainage investment left out to minimize costs
  - — Water allocation– virtually no cost, encouraging overuse, waterlogging and salinization

✓ Phase out water subsidies

✓ Secure water rights for users

✓ Establish markets in tradable water rights

✓ Devolve management to user or joint ownership with autonomous local institutions

Policy-induced Negative Consequences and Recommendations for Reform

- Input policies
  - Input subsidies – keeping input prices low directly affects crop management practices
    - Reduces farmer incentives for improving input use efficiency
    - Subsidized fertilizer prices favor the use of N fertilizers over other nutrients, creating imbalances in soil fertility

✓ Reduction and eventual removal of fertilizer price subsidies or replacement with 'smart' subsidies

✓ Non-price policies: location-specific research on soil fertility constraints and agronomic practices, improve extension, develop physical and institutional infrastructure

✓ Design unsubsized risk-reducing instruments: weather index insurance, risk-contingent credit

Policy-induced Negative Consequences and Recommendations for Reform

- Price and trade policy and sustainability
  - Macroeconomic setting leading to unsustainable management practices – cause of degradation of intensive food systems in Asia
  - General trade and exchange rate policies penalize agriculture across the board
  - Crop-specific interventions—output price protection and input subsidies—often favor individual crops like rice

✓ Remove macro- and price distortions

✓ Adopt cropping and livestock systems approaches

✓ Develop new resource-conserving technologies to reduce the economic and ecological cost per unit of output produced

Create and Expand Markets in Natural Resources

- Expand markets for environmental services (watershed management, biodiversity)
- Establish economic incentives for water use
- Develop markets for agricultural and forest greenhouse gases, generating new value streams in rural areas through GHG mitigation

Accelerate Investments in Agricultural Research and Development

Invest in technologies for

- Crop and livestock breeding
  - High-yielding varieties
  - Biotic- and abiotic-stress resistant varieties
- Modernize breeding programs in developing countries through provision of genomics, high throughput gene-sequencing, bio-informatics and computer tools
- GMOs where genetic variation does not exist in the crop
  - Nitrogen use efficiency
  - Drought, heat and salinity tolerance
  - Insect and disease resistance

Sequencing of Investments and Technologies

- Bad agricultural sustainability policies are persistent
- Need “bad-policy-resistant” investments and technologies
- Investment in public goods: education, roads, ports, agricultural research and development
- Technologies embedded in seed varieties
- Low external input cropping systems
- Decentralized information technologies: cell phone weather and crop information apps, small sensors, radio