



United States  
Department of  
Agriculture

National Institute  
of Food  
and Agriculture

INVESTING IN SCIENCE | SECURING OUR FUTURE | WWW.NIFA.USDA.GOV

# SETTING THE TABLE FOR A HOTTER | FLATTER | MORE CROWDED EARTH

SONNY RAMASWAMY

BIOTIC

ABIOTIC

FOOD  
WASTE/LOSS

FARMING  
SYSTEMS

POLICIES

PATH  
FORWARD



SETTING THE TABLE FOR A **HOTTER** | **FLATTER** | **MORE CROWDED** EARTH

# also Wicked Problems

societal challenges

- Population
- Food
- Water
- Environment
- Climate Change
- Energy
- Health
- Poverty

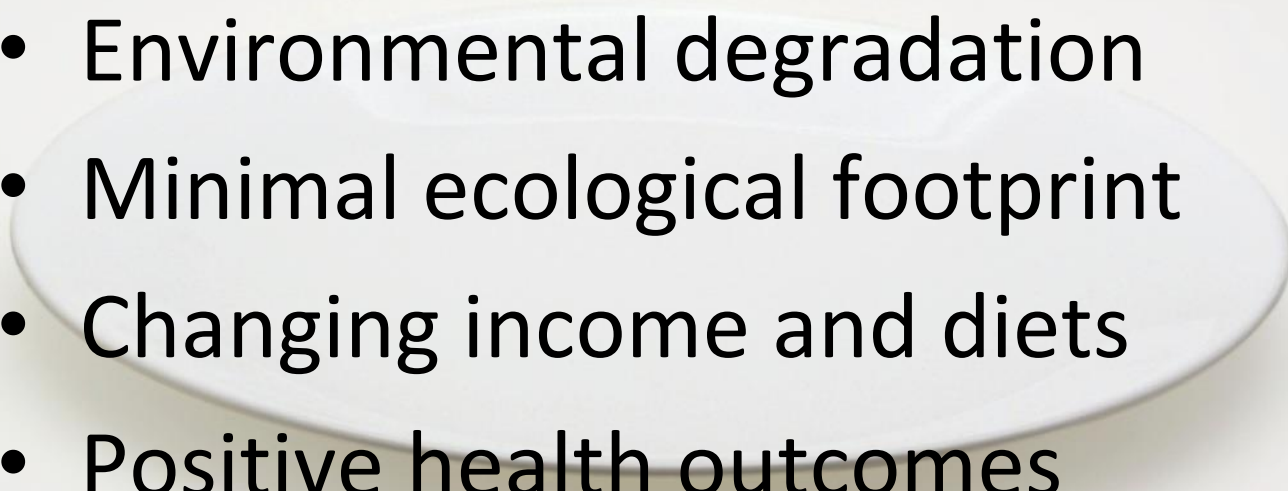


# 21<sup>st</sup> Century Food System Challenges

- **Agricultural Competitiveness**
  - Improve crop and animal agriculture; enhance farm productivity and income; policies; supply chain; storage; transportation
- **Ecological Footprint**
  - Water/land use, natural resource and environmental stewardship, greenhouse gas, global climate change, depleted soils
- **Bioeconomy**
  - Replacements for petroleum-based products and enhance community economic well being
- **Health**
  - Food safety, nutrition, obesity, type II diabetes, cardiovascular disease, dementia, cancer, hunger, poverty, families/children

# Feed, shelter, clothe > 9 billion

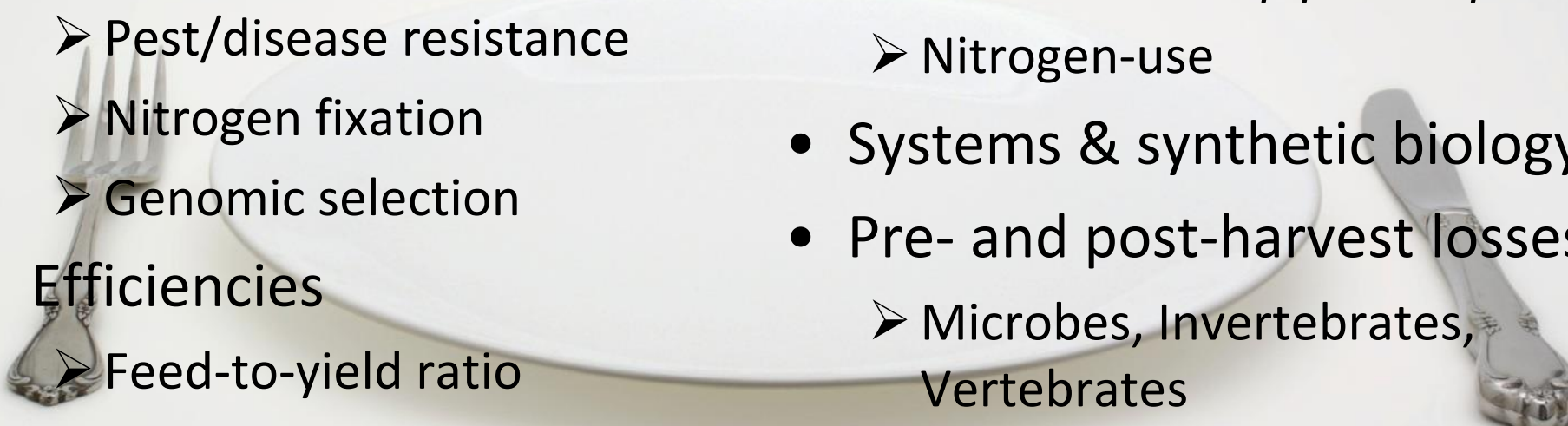
- Climate change
- Land and water constraints
- Increasing urbanization
- Environmental degradation
- Minimal ecological footprint
- Changing income and diets
- Positive health outcomes



# The Nexus



# Biotic Constraints

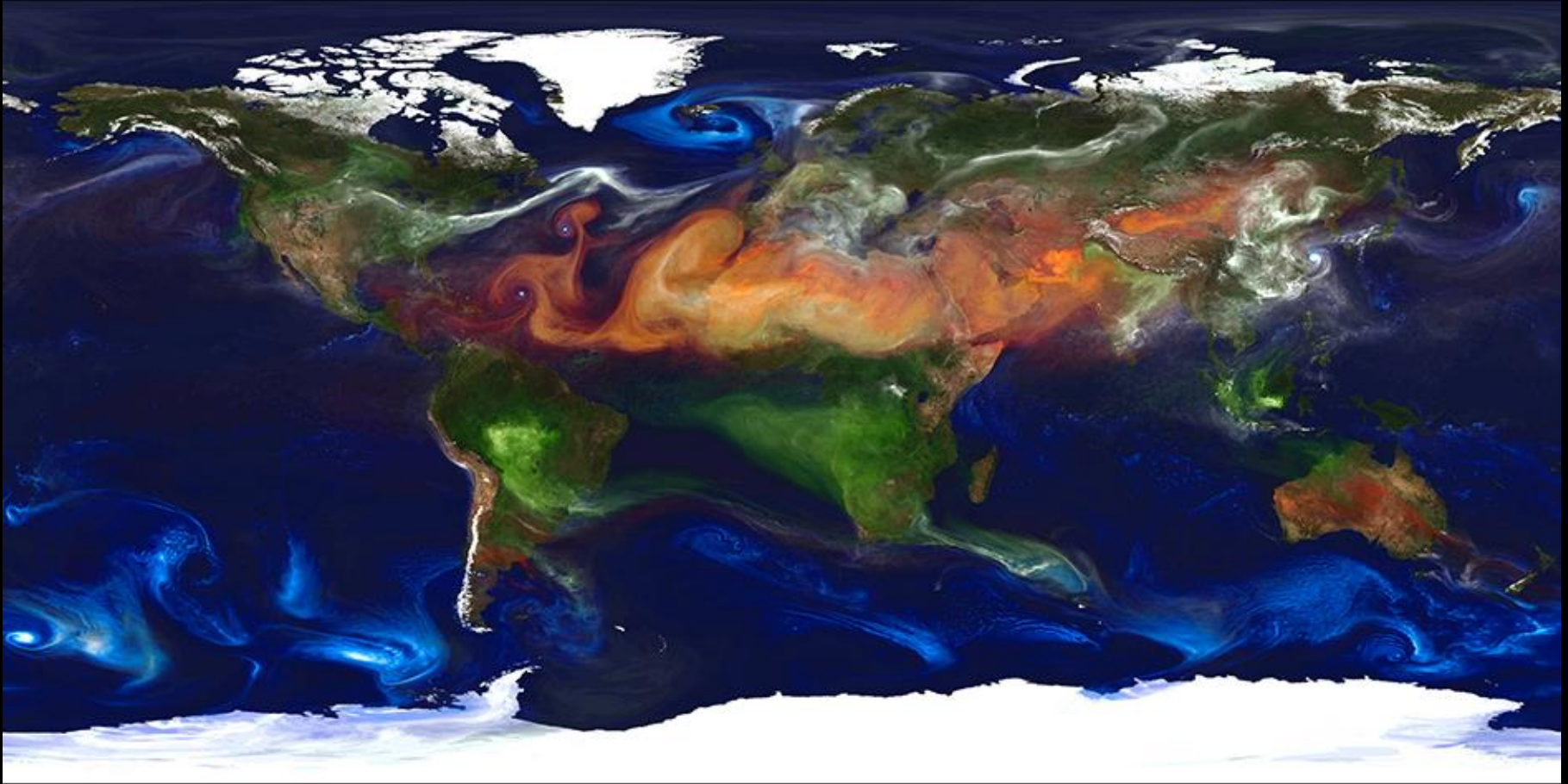
- 
- Diversity of species
    - 50,000 edible; 15-50 used
  - Traits
    - Yield/productivity
    - Yield stabilization: GxExM
    - Pest/disease resistance
    - Nitrogen fixation
    - Genomic selection
  - Efficiencies
    - Feed-to-yield ratio
  - Heat tolerance
  - Photosynthesis: *C3 to C4*
    - Scarecrow gene (Slewinski and Turgeon 2013)
  - Cisgenics vs Transgenics
  - Water-use: *Crop per Drop*
  - Nitrogen-use
  - Systems & synthetic biology
  - Pre- and post-harvest losses
    - Microbes, Invertebrates, Vertebrates

# Abiotic Constraints

- Soil depletion
- GHGs and Climate Change



## Portrait of Global Aerosols



Portrait of global aerosols produced by a GEOS-5 simulation. Dust (red) is lifted from the surface, sea salt (blue) swirls inside cyclones, smoke (green) rises from fires, and sulfate particles (white) stream from volcanoes and fossil fuel emissions. *Image credit: William Putman, NASA/Goddard*



# Abiotic Constraints

- Soil depletion
- GHGs and Climate Change
- Correlation between yield and temperature
  - 4°C increase: crop failures, malnutrition
  - Livestock/aquatics responses



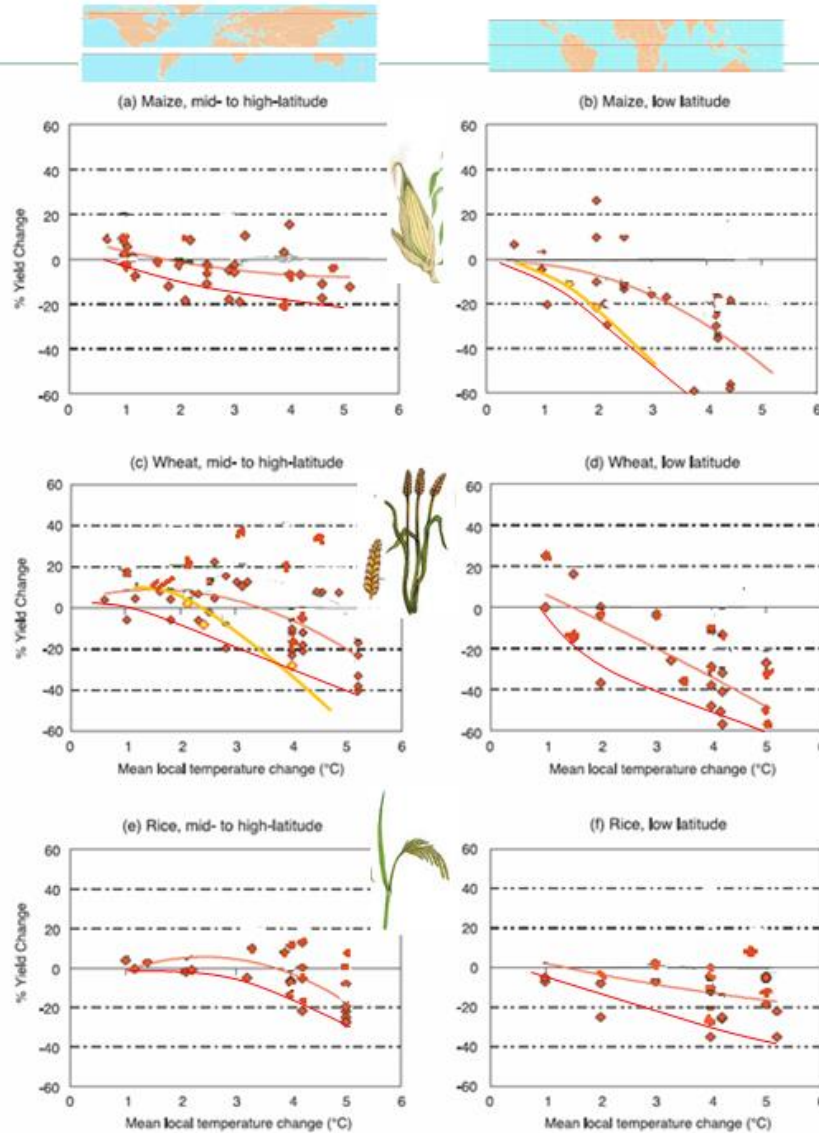
## IPCC climate crop model ensemble with risk averse crop declines added (red)

Best-fit polynomials

Rain fed reduced precipitation

Best fit most risk averse added

Lines are best-fit polynomials and are used here as a way to summarise results across studies rather than as a predictive tool.



P 286

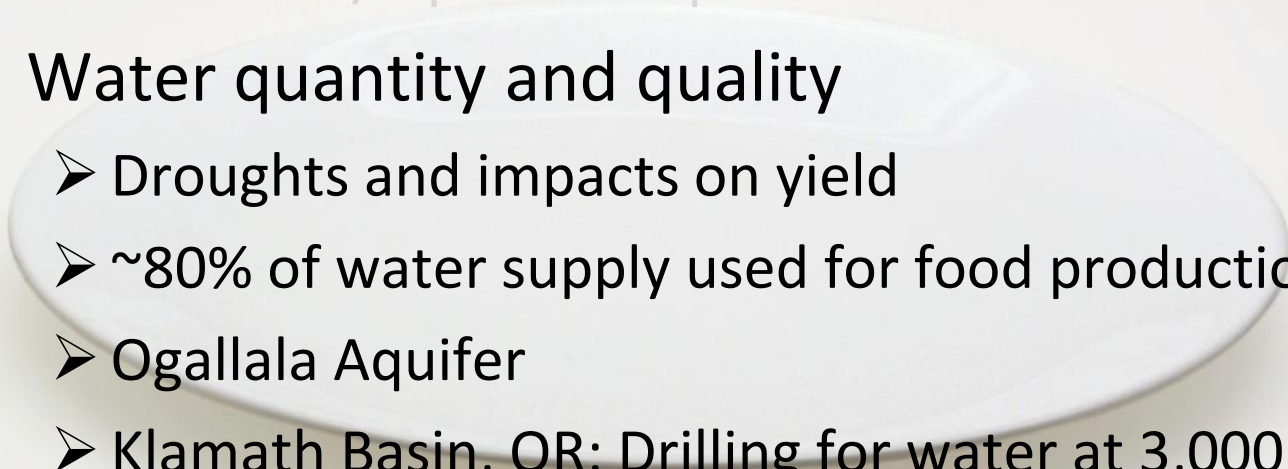
<http://www.climatechange-foodsecurity.org/ipcc.html>

IPCC climate crop models AR4 4 2007 WG 2 Ch 4

Fig 5.2

# Abiotic Constraints

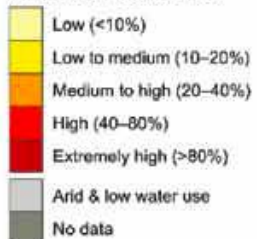
- Soil depletion
- GHGs and Climate Change
- Correlation between yield and temperature
  - 4°C increase: crop failures, malnutrition
  - Livestock/aquatics responses
- **Water quantity and quality**
  - Droughts and impacts on yield
  - ~80% of water supply used for food production
  - Ogallala Aquifer
  - Klamath Basin, OR: Drilling for water at 3,000 ft



# Water Stress

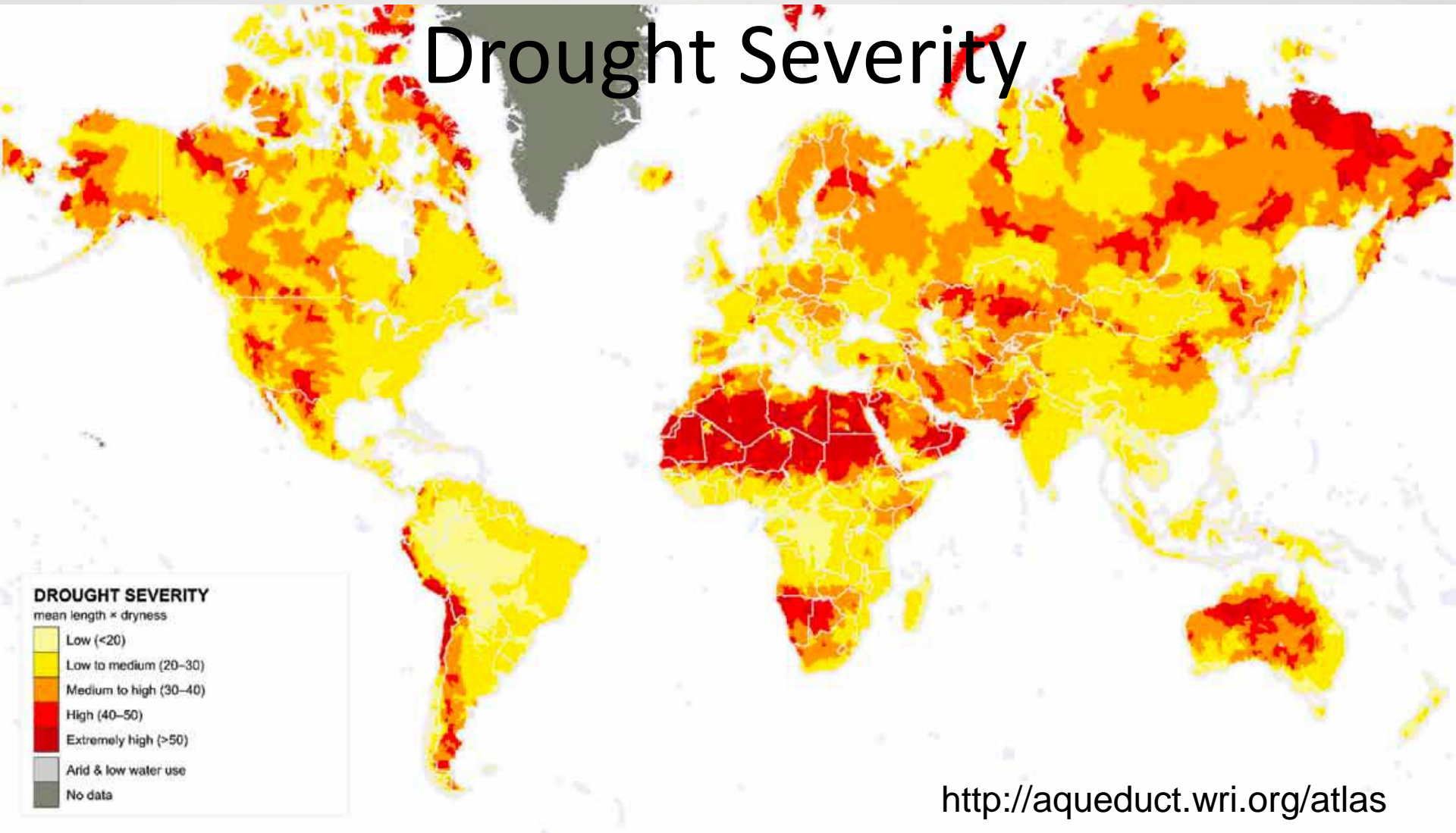
## **BASILINE WATER STRESS**

withdrawals / available flow



<http://aqueduct.wri.org/atlas>

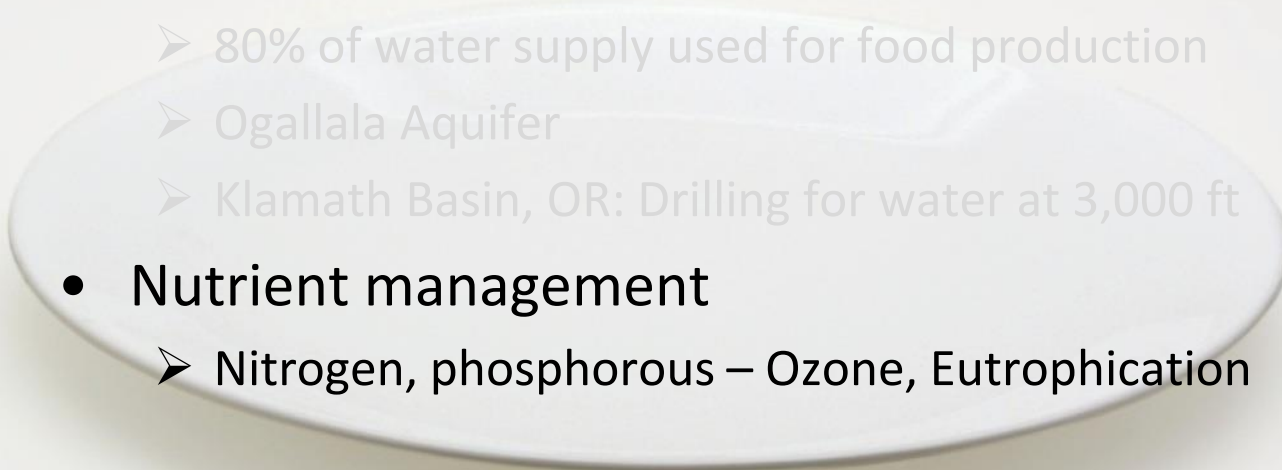
# Drought Severity



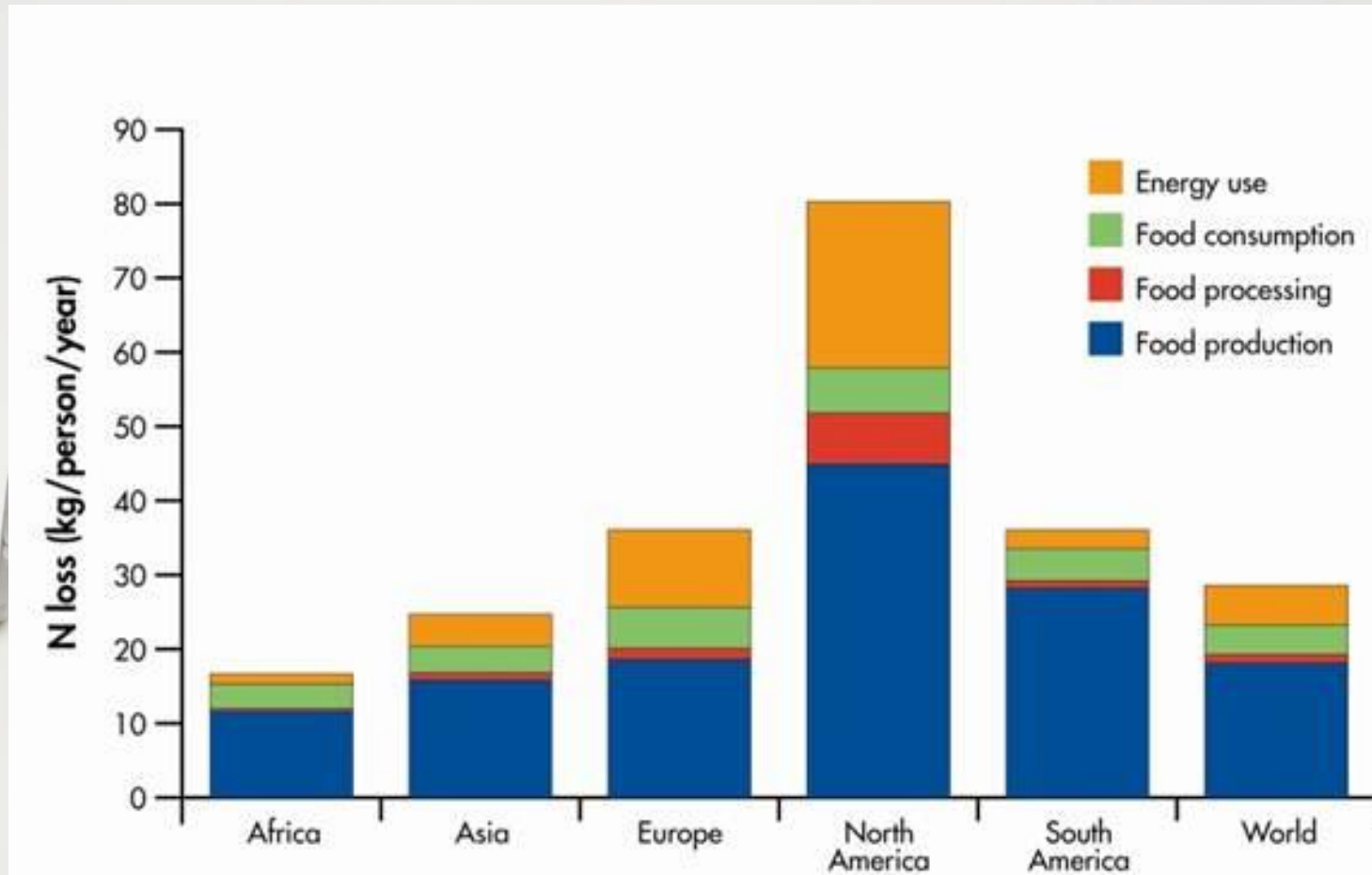
<http://aqueduct.wri.org/atlas>

# Abiotic Constraints

- Soil depletion
- GHGs and Climate Change
- Correlation between yield and temperature
  - 4°C increase: crop failures, malnutrition
- Water quantity and quality
  - Droughts and impacts on yield
  - 80% of water supply used for food production
  - Ogallala Aquifer
  - Klamath Basin, OR: Drilling for water at 3,000 ft
- **Nutrient management**
  - Nitrogen, phosphorous – Ozone, Eutrophication

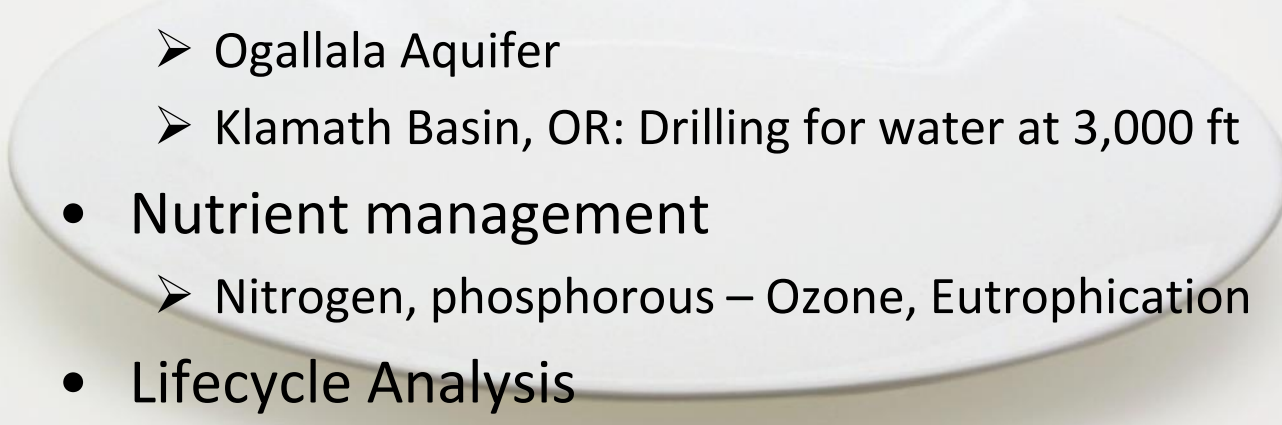


# Nitrogen Loss Indicator



# Abiotic Constraints

- Soil depletion
- GHGs and Climate Change
- Correlation between yield and temperature
  - 4°C increase: crop failures, malnutrition
- Water quantity and quality
  - Droughts and impacts on yield
  - 80% of water supply used for food production
  - Ogallala Aquifer
  - Klamath Basin, OR: Drilling for water at 3,000 ft
- Nutrient management
  - Nitrogen, phosphorous – Ozone, Eutrophication
- Lifecycle Analysis



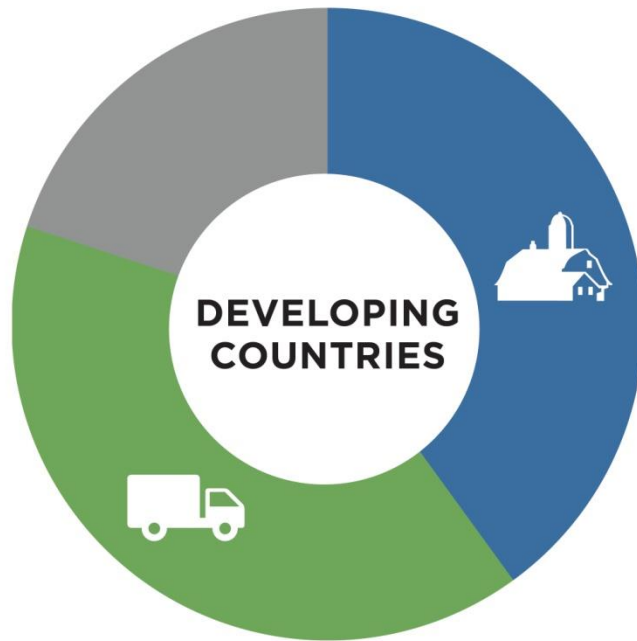


# Most Significant/Immediate Abiotic Constraints

- Arable land
- Water
- Labor
- Climate
- Capital
- Logistics
- Mechanization



## FOOD WASTE / FOOD LOSS



- Double food production in 40 years
- Cut loss/waste by half?
- Impact climate change

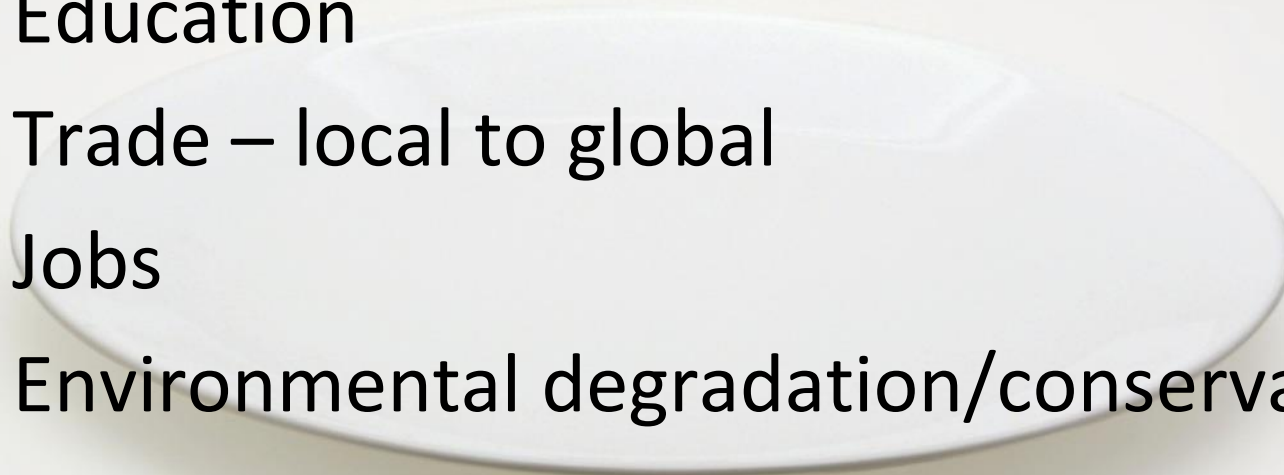
- On-Farm
- Transport & Processing
- Retail
- Food Service
- Home & Municipal
- Retail, Food Service, Home & Municipal (combined)

# Farming systems

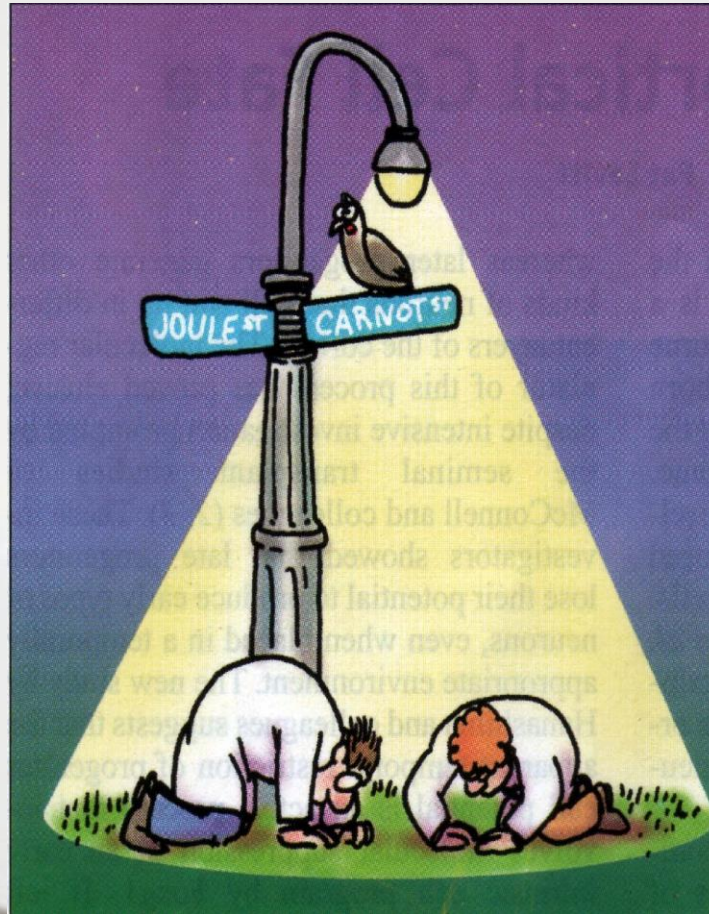
- Improved technologies
  - Productivity gap: 1.5 → 2%
  - Peak farmland – Ausubel et al. 2013
- Closed loop systems
- Cooperatives – Kibbutz?
- Integrated/diversified
- Logistics and mechanization
- Smart farming
  - Robotics, sensors, sentinels
- Resilient intensification
  - Policies and consequences
- Vertical farming
- Hydroponics
- Aquaponics

# Policies/Regulation/Marketing

- Governance
- Socially beneficial policies, programs
- Poverty reduction
- Education
- Trade – local to global
- Jobs
- Environmental degradation/conservation



# Path Forward: New Paradigms

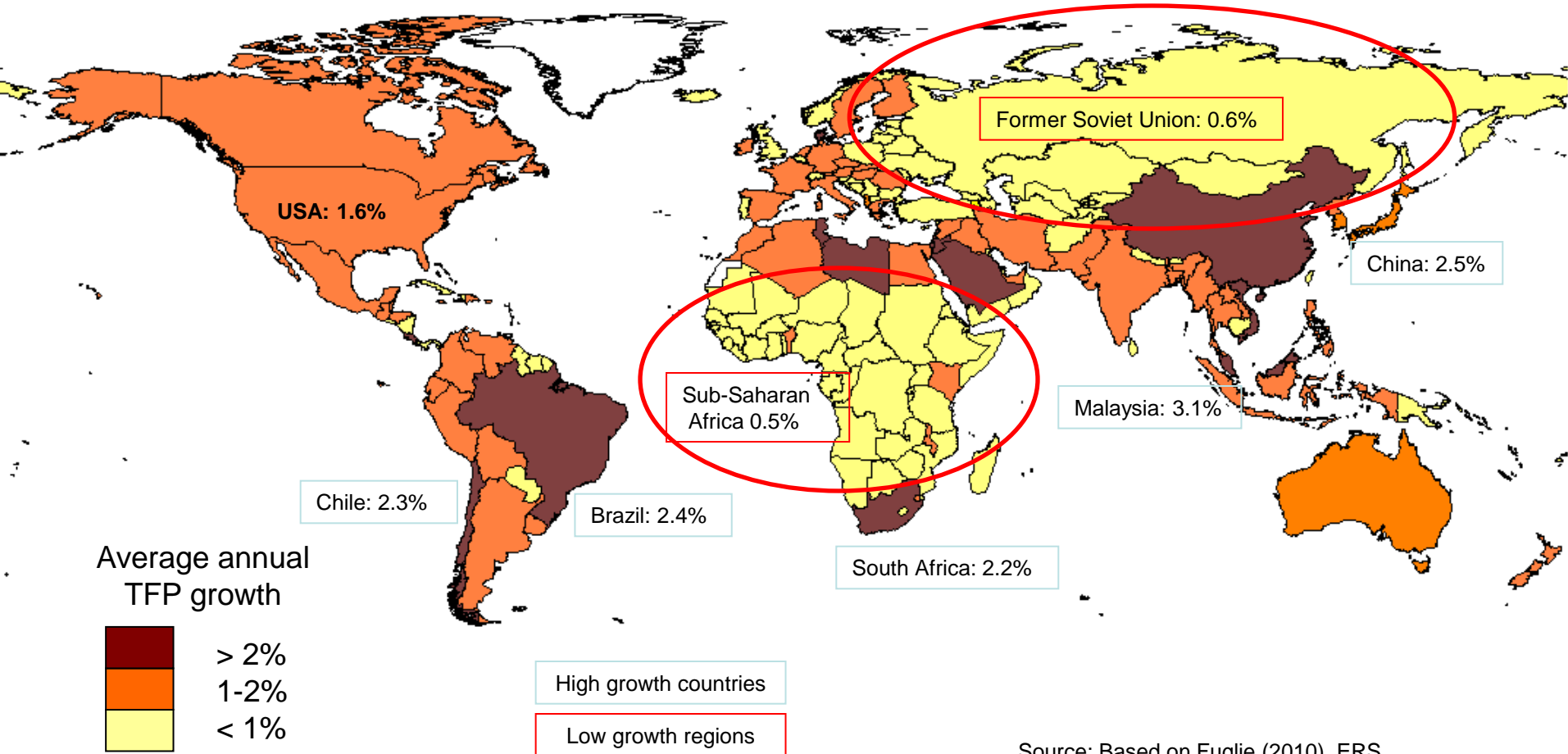


# Path Forward

- Virtual water and nitrogen
  - True costs?
- Transformative approaches
  - Perennial/multi cropping
  - Conversion of deserts?
  - Algae in oceans?
  - Bio-/nano-technology
  - Modern Meadow, Inc.
    - 3-D printing
  - Beyond Meat, Inc.
- Logistics and mechanization
- Pest management
- Education & Extension
- Big data: [data.gov/agriculture](http://data.gov/agriculture)
- Policy research
- Partnerships
  - Governments
  - NGOs
  - Private
  - Academic
- Research investments



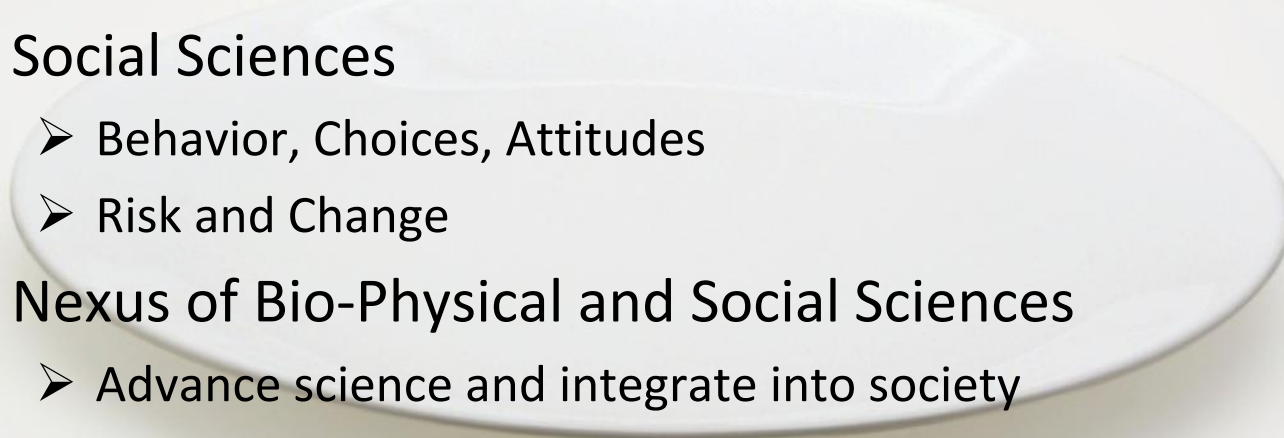
# Agricultural TFP growth by country, 1970-2007



Source: Based on Fuglie (2010), ERS.

# Humans Matter

- Consumers, businesses, groups, communities, towns, states and countries make decisions
  - Information-dependent: Haves and Havenots
- Acceptance of technologies
- People impacts
  - Technical, Policy, Regulatory, and Social Change
- Social Sciences
  - Behavior, Choices, Attitudes
  - Risk and Change
- Nexus of Bio-Physical and Social Sciences
  - Advance science and integrate into society





# Path Forward

## G20 Principles – Six Strategic Platforms

A white plate is centered on the page, with six colored rectangular boxes arranged in a 3x2 grid on top of it. To the left of the plate is a silver fork, and to the right is a silver butter knife. The boxes contain the following text: 'Open Access to Scholarly Publications' (blue), 'Open Access to Germplasm Collections' (red), 'Open Access to Genetic and Genomic Data' (black), 'Accelerated Technology Transfer' (green), 'Improved Statistics' (orange), and 'Improved Extension' (purple).

Open Access  
to Scholarly  
Publications

Open Access  
to Germplasm  
Collections

Open Access  
to Genetic and  
Genomic Data

Accelerated  
Technology  
Transfer

Improved  
Statistics

Improved  
Extension

# SETTING THE TABLE FOR A HOTTER | FLATTER | MORE CROWDED EARTH

BIOTIC

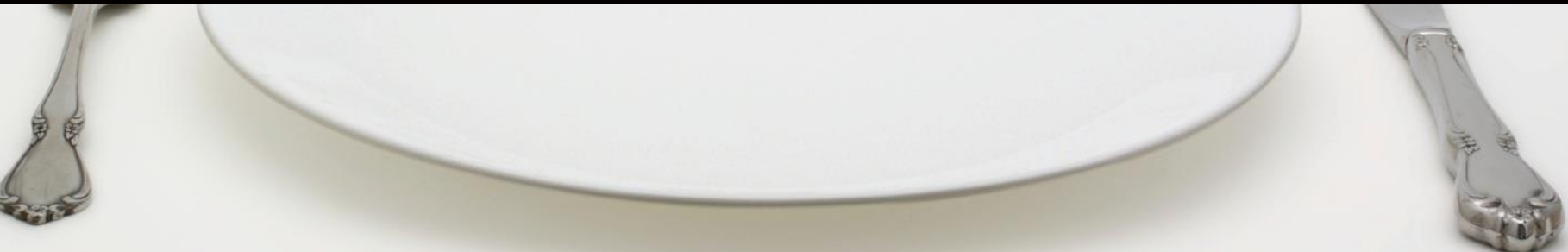
ABIOTIC

FOOD  
WASTE/LOSS

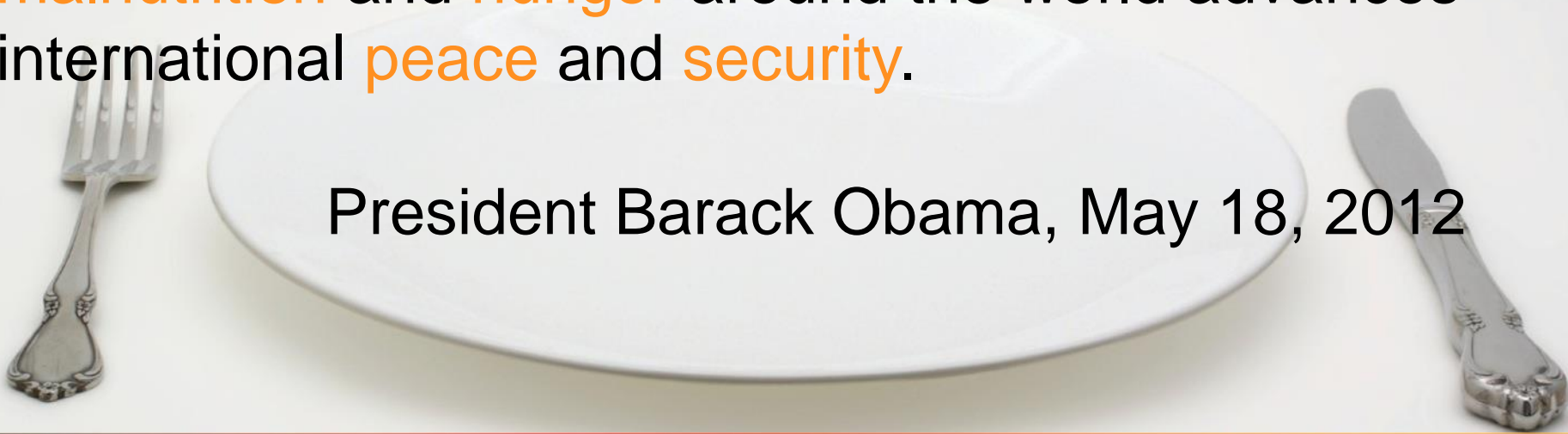
FARMING  
SYSTEMS

POLICIES

PATH  
FORWARD



We've seen how **spikes in food prices** can plunge millions into **poverty**, which in turn can cause **riots** that cost lives and can lead to **instability**. And this danger will only grow if a surging global **population** isn't matched by surging food **production**. So reducing **malnutrition** and **hunger** around the world advances international **peace** and **security**.

A white oval plate is centered on a light gray surface. To the left of the plate is a silver fork, and to the right is a silver butter knife. The text "President Barack Obama, May 18, 2012" is overlaid on the plate.

President Barack Obama, May 18, 2012



United States  
Department of  
Agriculture

National Institute  
of Food  
and Agriculture

Current World Population 7,045,879, ~~800~~

INVESTING IN SCIENCE | SECURING OUR FUTURE | [WWW.NIFA.USDA.GOV](http://WWW.NIFA.USDA.GOV)



SETTING THE TABLE FOR A **HOTTER** | **FLATTER** | **MORE CROWDED** EARTH