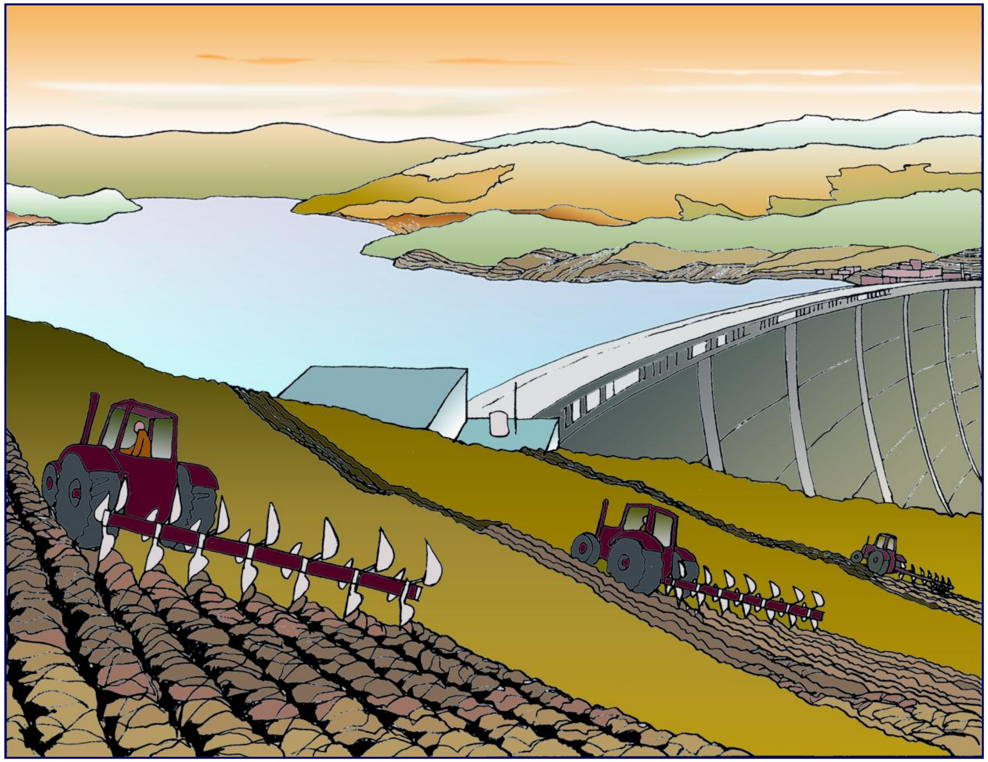
Land, Water and Climate Change Adaptation

Steve Carpenter (srcarpen@wisc.edu)



University of Wisconsin
Center for Limnology

The Beijer Institute of Ecological Economics

LTER

SARA(S)^2
Instituto Sudamericano de Ciencias de la Sustentabilidad y Resiliencia

South American Institute for Resilience and Sustainability Studies

Topics for the Talk:

Trends and links

Water withdrawals

Biogeochemical cycles

What could we do about it?

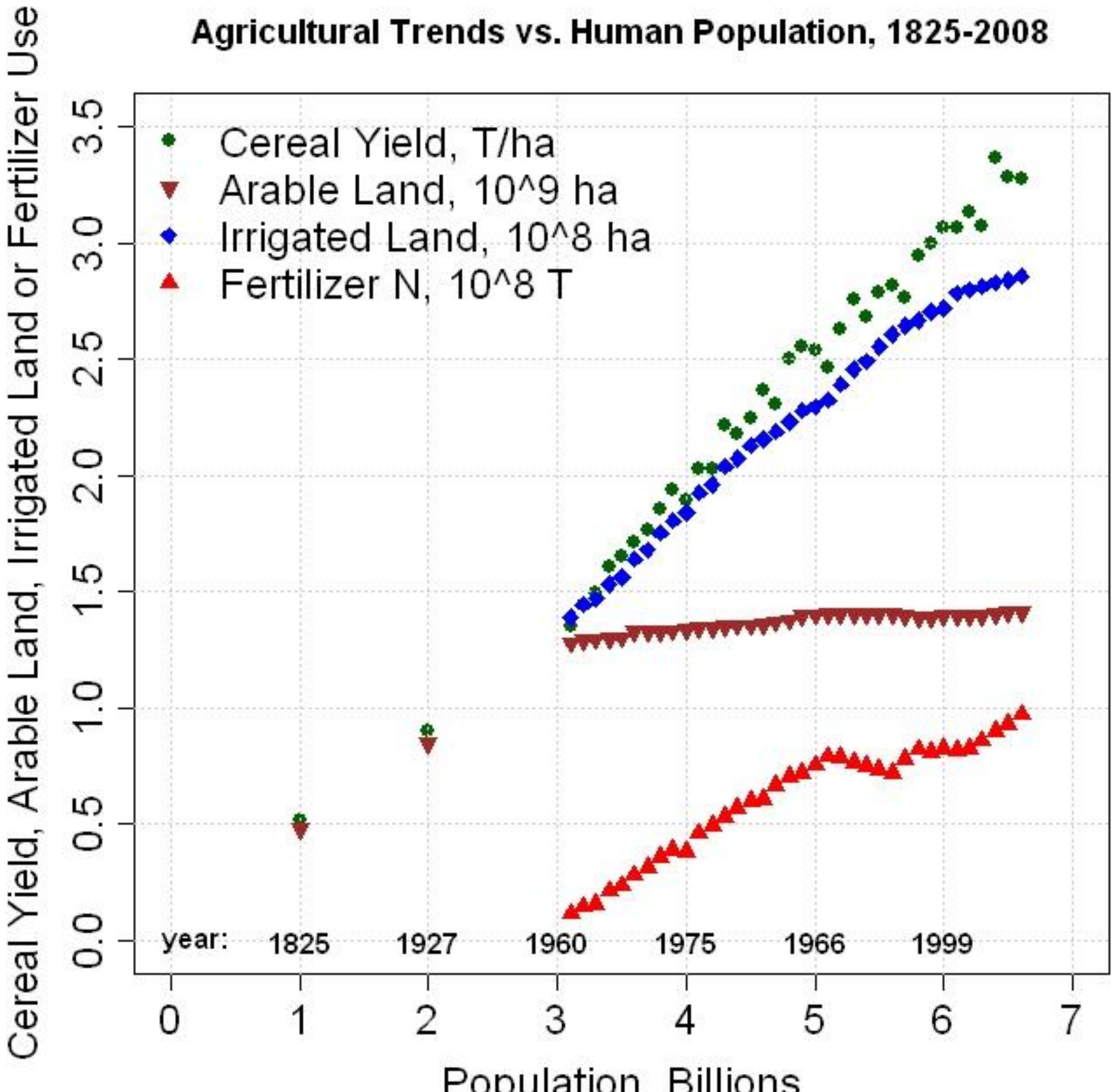
Topics for the Talk:

Trends and links

Water withdrawals

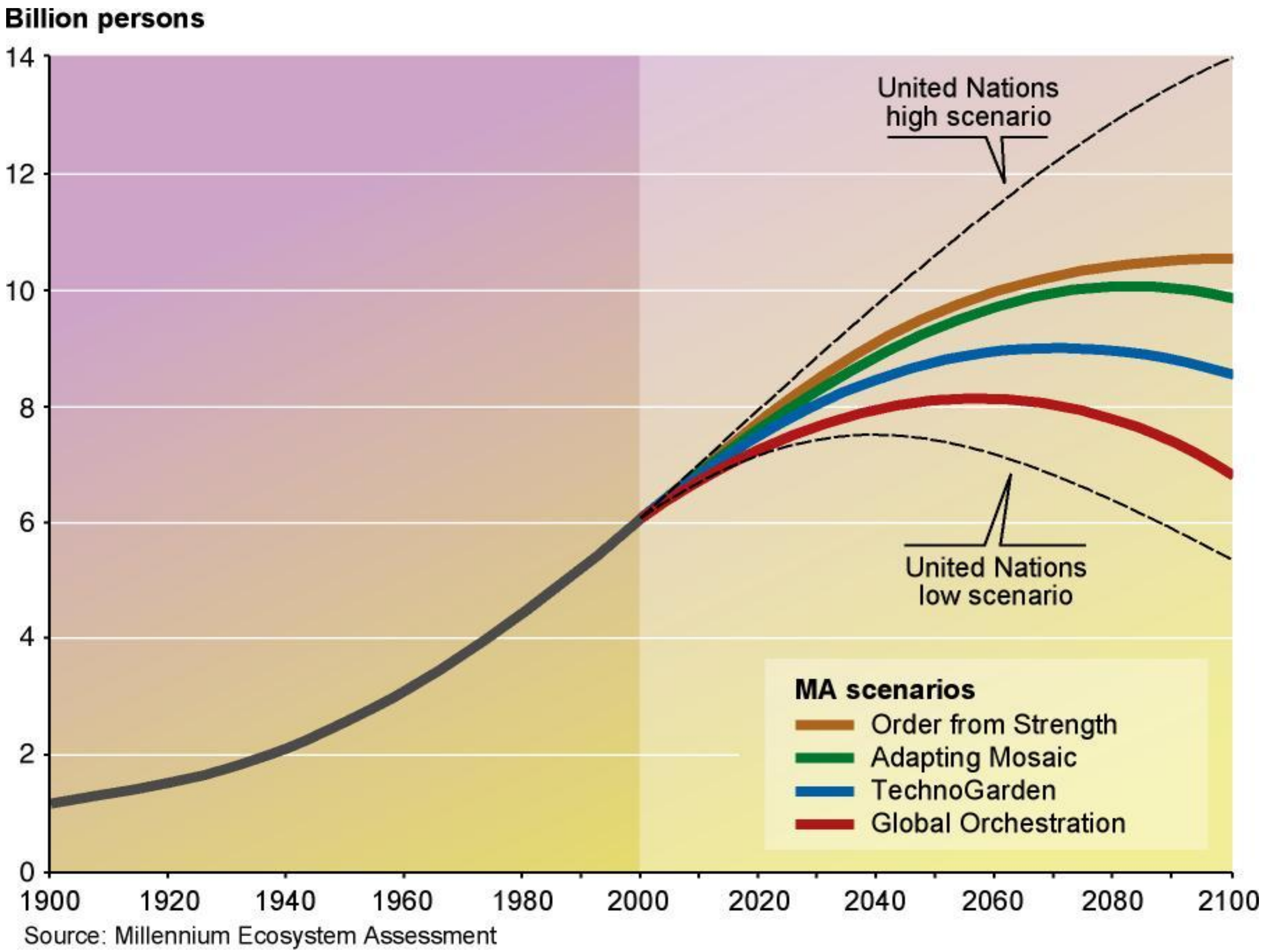
Biogeochemical cycles

What could we do about it?

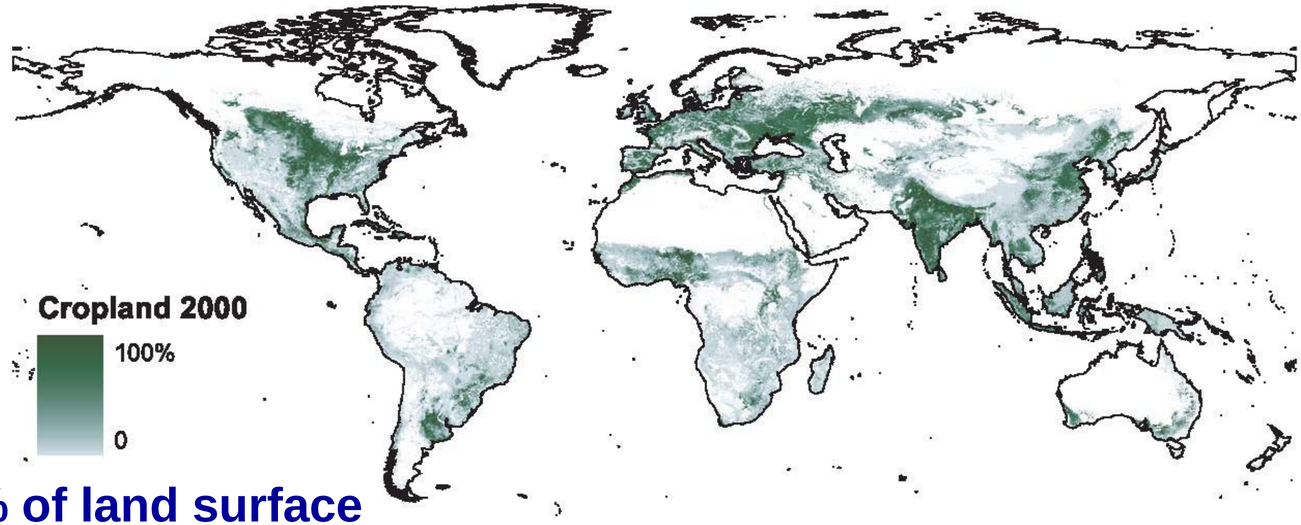


Cohen, J. 2002. Future of population. In: Cooper & Layard, *What the Future Holds*. MIT Press. Redrawn from Evans, 1998, *Feeding the Ten Billion*, Cambridge Univ. Press. Updated to 2008 by J. Fabina and S. Carpenter using data from FAO and IFA.

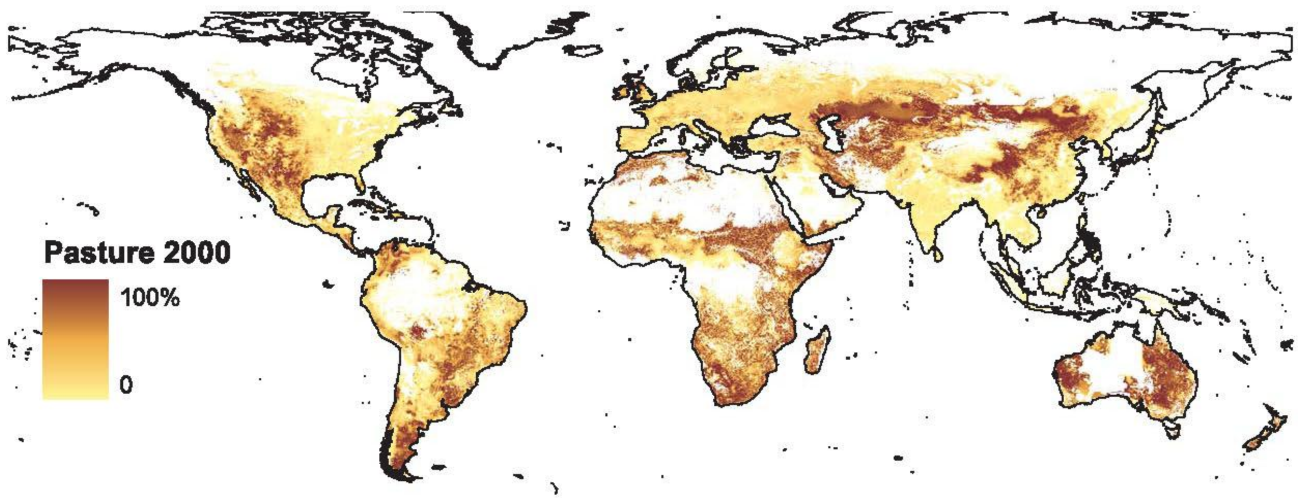
Population Projections: MA Scenarios



Agricultural Area

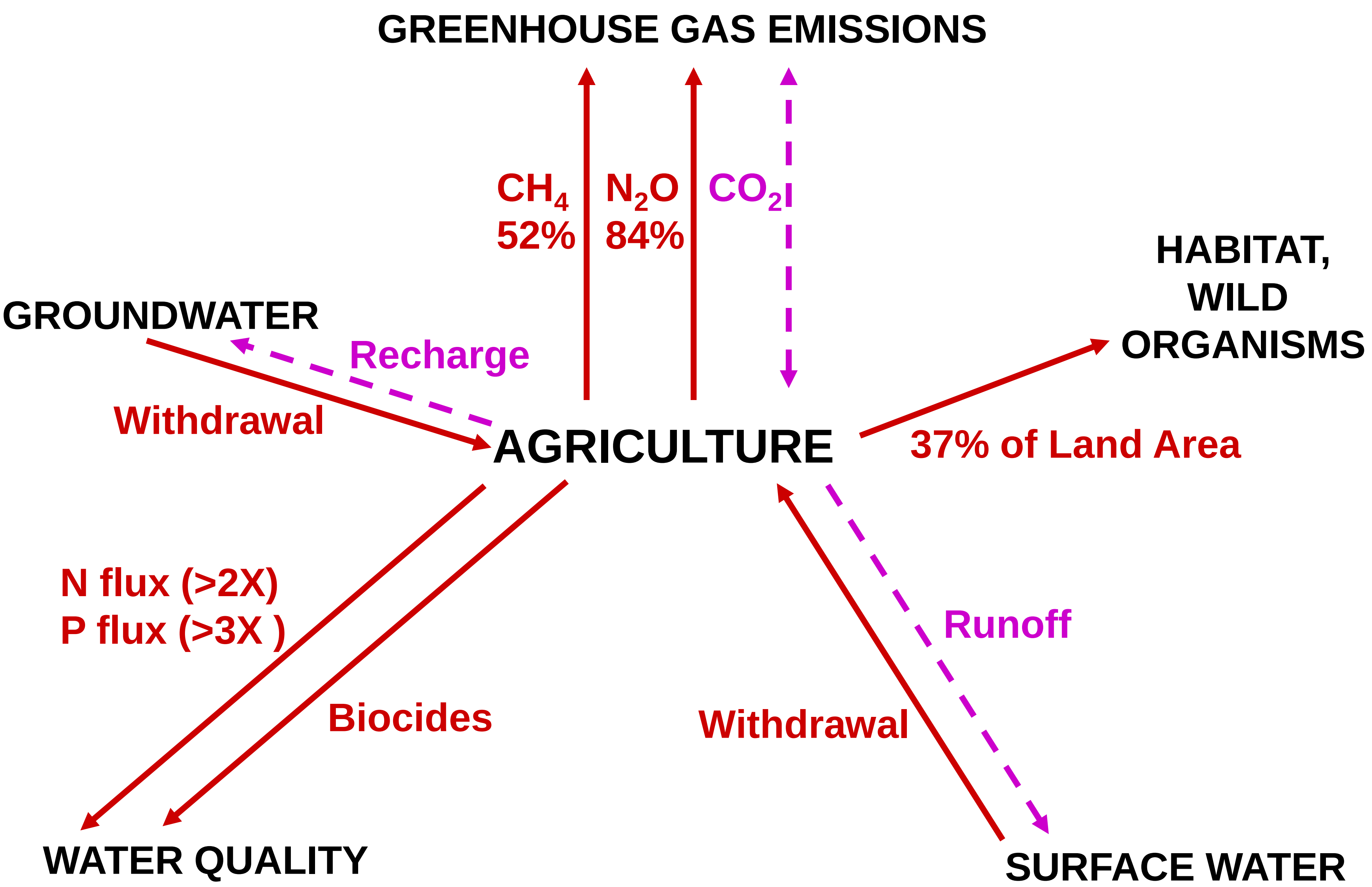


~13% of land surface



~24% of land surface

Ramankutty et al., 2008, Global Biogeochemical Cycles


GREENHOUSE GAS EMISSIONS
CH_4 52%
N_2O 84%
CO_2
HABITAT, WILD ORGANISMS
GROUNDWATER
Recharge
Withdrawal
AGRICULTURE
37% of Land Area
N flux (>2X)
P flux (>3X)
Runoff
Biocides
Withdrawal
WATER QUALITY
SURFACE WATER

Topics for the Talk:

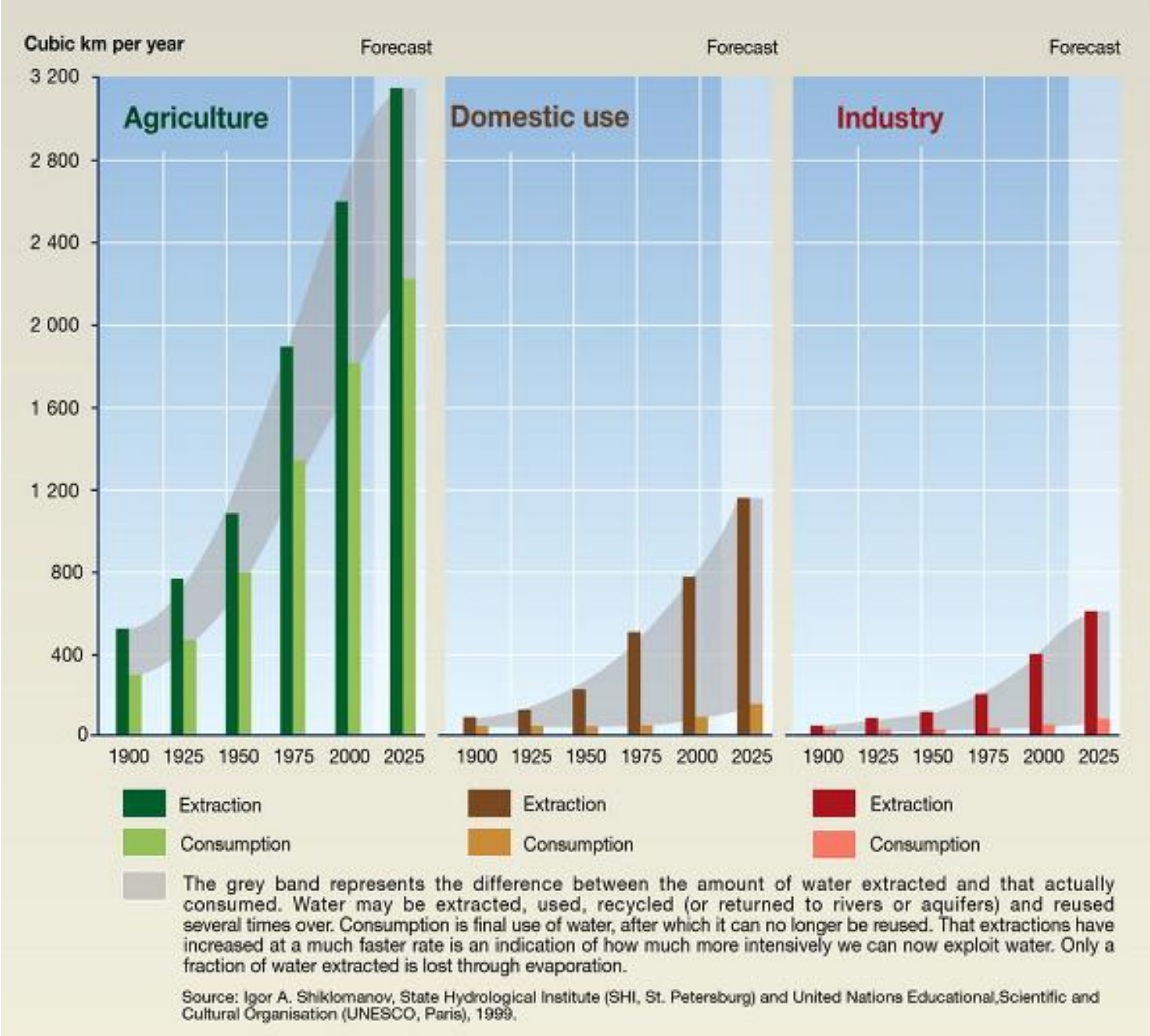
Trends and links

Water withdrawals

Biogeochemical cycles

What could we do about it?

Global International Water Assessment
http://www.grida.no/publications/vg/water2/



Groundwater:

~25% of global water withdrawals; ~50% of the world's potable water

1.5 to 2.8 B people drink groundwater , including more than half the world's megacities (>10M people)

Withdrawal / renewal ratio varies hugely among countries:

Lowest and Highest: 0.4% Brazil, 950% Saudi Arabia

High-population countries: China 6.5%, India 43%

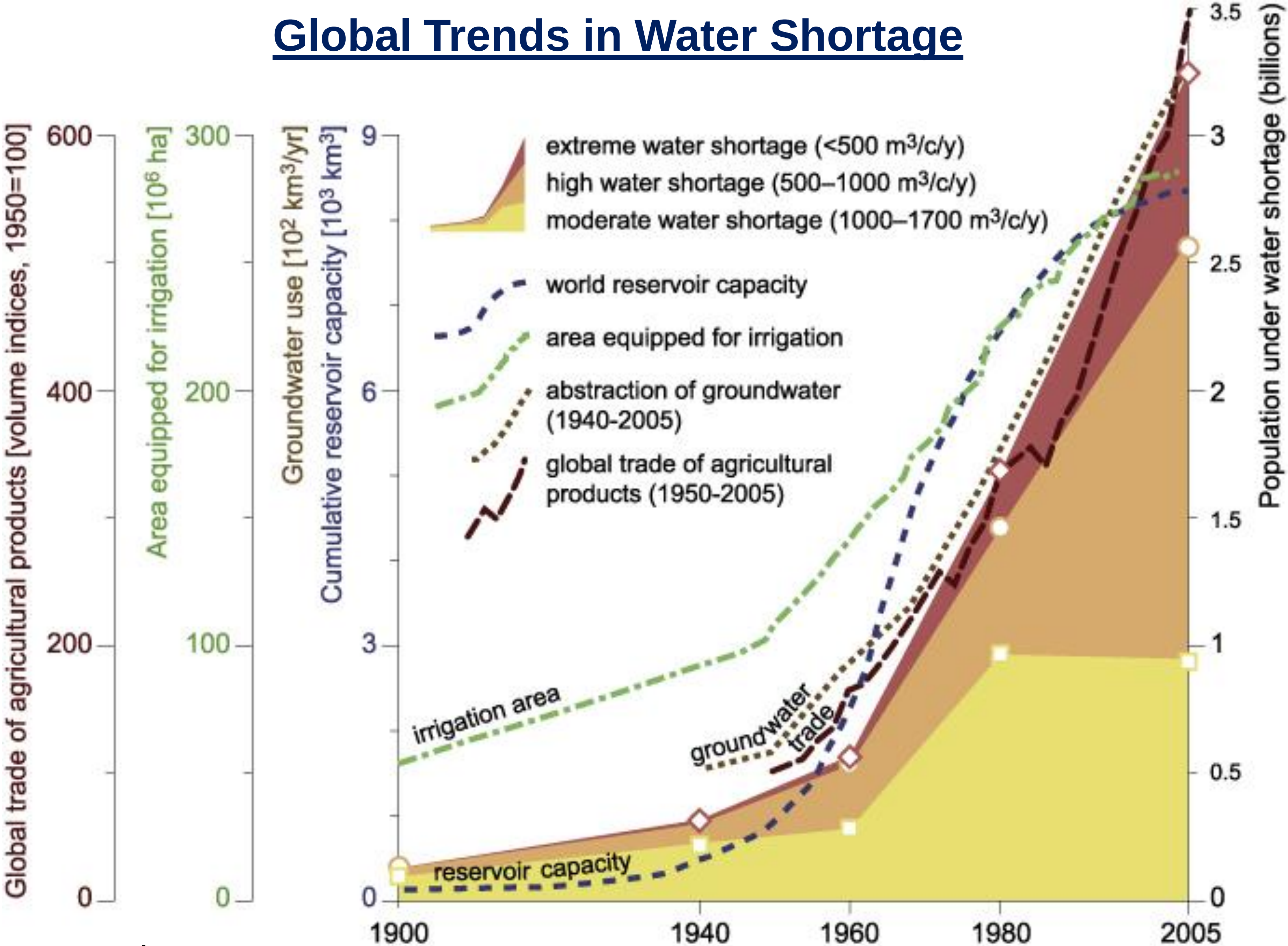
U.S. 8.5%

Global average 5.8%

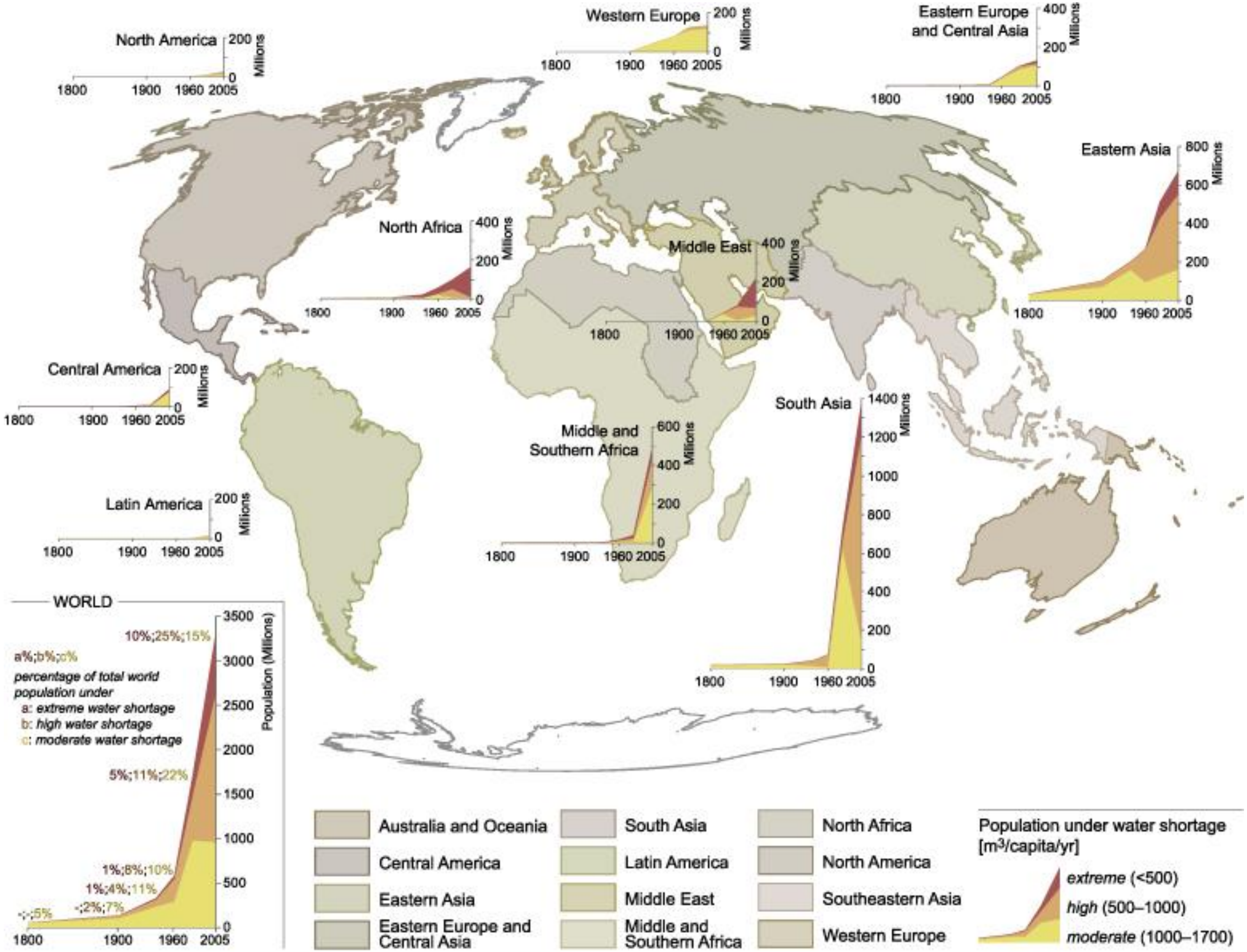
"Institutions for managing groundwater sustainably have universally failed".

Giordano, M. 2009. Annu. Rev. Environ. Resour. 34:153–78

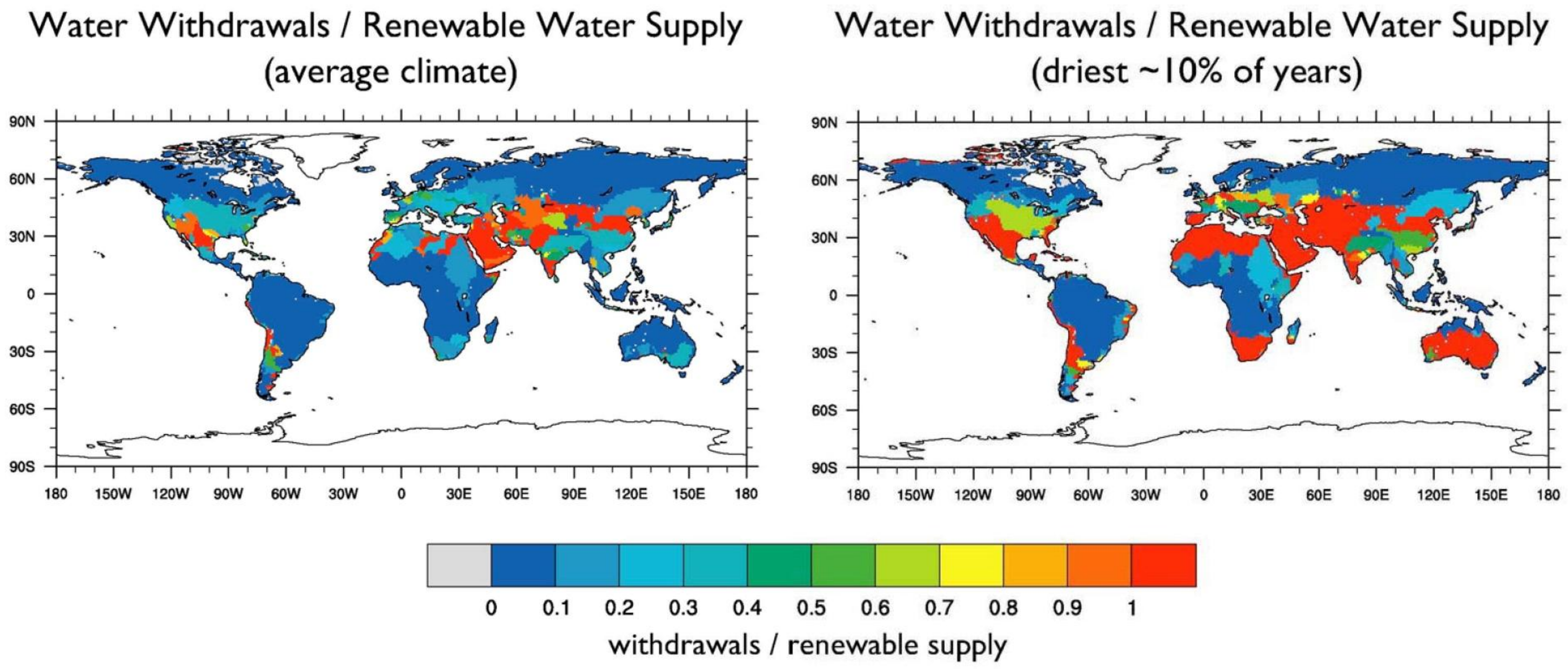
Global Trends in Water Shortage



Kummu et al., ERL 2010



Kummu et al., ERL 2010



Foley et al. 2005, Science 309:570-574.

Topics for the Talk:

Trends and links

Water withdrawals

Biogeochemical cycles

What could we do about it?

Human-Driven Changes in Biogeochemical Cycles

Element	Natural Flux (10^6 MT/year	Human Flux (10^6 MT/year	% Change from Human Activity	Explanation
C	61,000	8,000	+13	Terrestrial total respiration; Fossil fuel and land use C
N	130	140	+108	Natural biological fixation; Fertilzers, combustion, rice
P	12.5	18.5	+248	Weathering; Mining
S	80	90	+113	Natural emissions; Fossil fuel + biomass burning
H & O	111×10^{12}	18×10^{12}	+16	As Water; Preciptation over land; Human use
Sediment	1×10^{10}	2×10^{10}	+200	Preindustrial suspended load: Modern suspended load

Falkowski et al. 2000, Science 290: 291-296; Bennett et al. 2001, BioScience 51: 227-234

Eutrophication & Harmful Algal Blooms

Red tide, Maine, USA

Cyanobacteria, Chaohu Lake, China

Opportunities for Innovative Management Of Biogeochemistry

Phosphorus recycling: retain P on land to maintain high water quality and avoid cost increases as global P reserves decline and P exporters (China, Morocco, U.S.) raise prices

"Designer crops": adapt landraces to local conditions for efficient yield while maintaining soil and water quality

Adapt practices to store carbon: 14% of global GHG emissions can be offset by agriculture if carbon price reaches $100/ton

Topics for the Talk:

Trends and links

Water withdrawals

Biogeochemical cycles

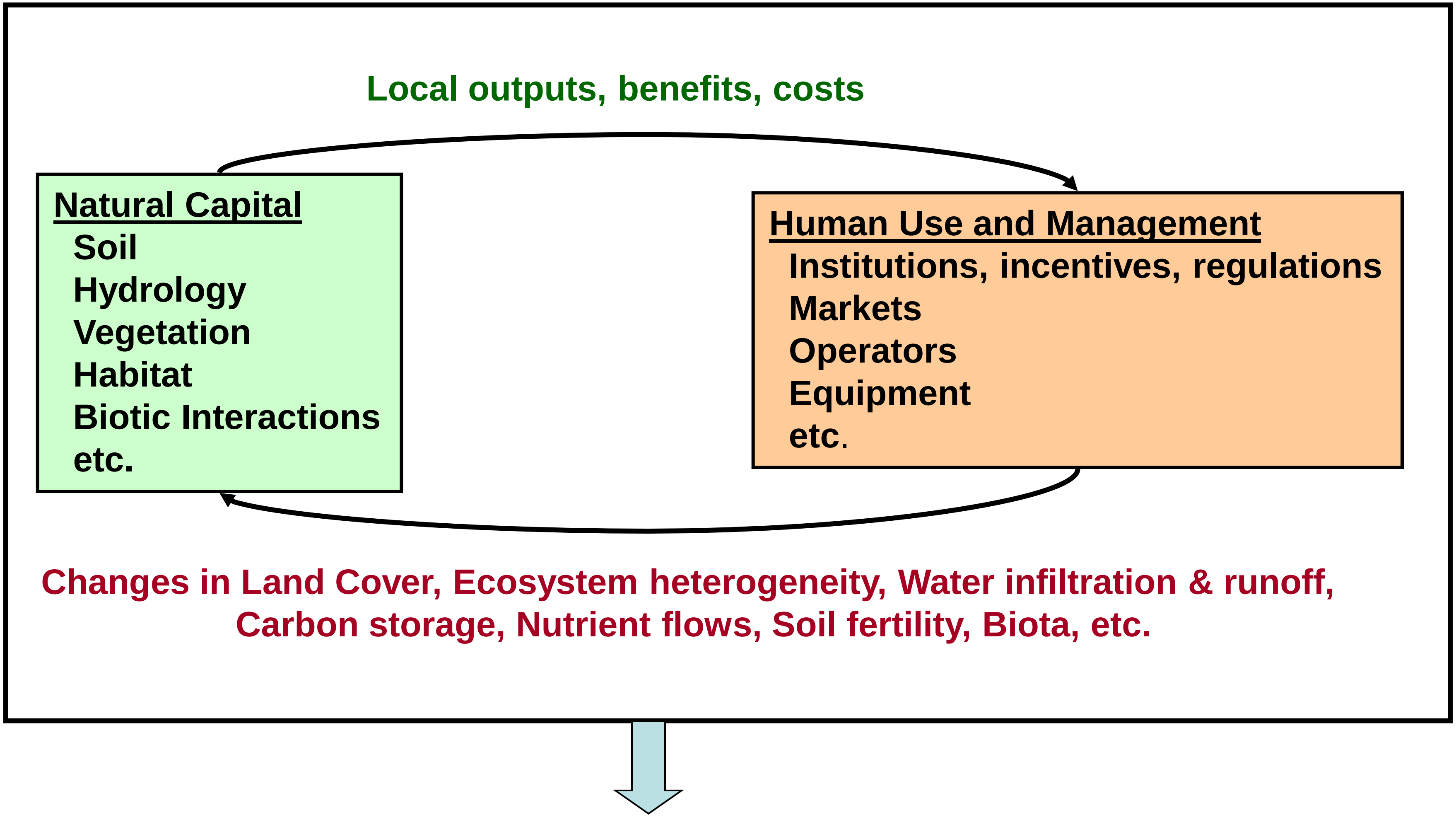
What could we do about it?

What Could We Do About It?

“Complete Accounting”: Include water, nutrients, carbon, habitat and wild species in decision frameworks for agriculture

Innovate a lot faster: Make local innovation a global trend.

Natural Capital and Ecosystem Services of an Agricultural Watershed



Ecosystem Services: Food & Fiber Production, Freshwater, Flood Regulation, Nutrient Regulation, Carbon Sequestration, Recreation, Aesthetics, etc.

Carpenter, Matson & Turner, unpublished

Create a Global Pattern of Local Innovation

Increase production efficiency (production per unit fertilizer, land, water).
Increase diversity of crops and adaptability to changing conditions.
Increase human well-being per unit crop production.

CONCLUSIONS

The future depends on inventing a new global agriculture:

- **High yield**
- **Carbon-neutral or better**
- **Does not overdraw water**
- **Does not emit P and reactive N**
- **Friendly to land and wild organisms**
- **Resilient to changing conditions**

CONCLUSIONS

The future depends on inventing a new global agriculture:

- High yield
- Carbon-neutral or better
- Does not overdraw water
- Does not emit P and reactive N
- Friendly to land and wild organisms
- Resilient to changing conditions

This requires new interdisciplinary work:

- Agricultural sciences
- Terrestrial & atmospheric environmental sciences
- Economics
- Institutional design
- Etc.

Some Specific Issues for Latin America

Virtual water trade: how will exports of water-demanding commodities affect water budgets?

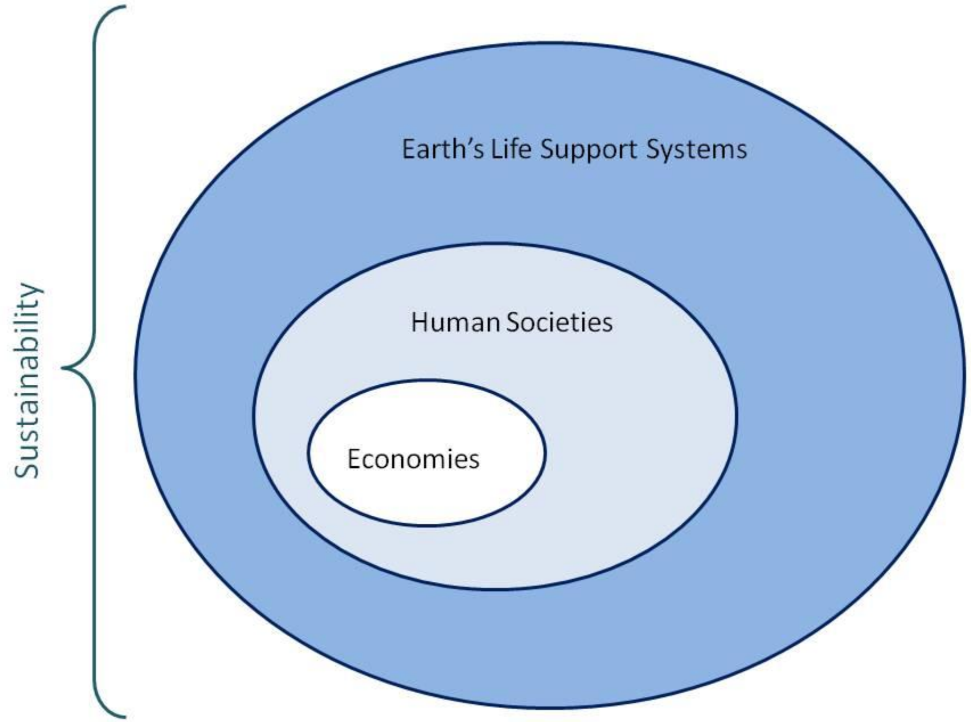
Virtual nutrient trade: how will exports of nutrient-rich meat and soy affect nutrient budgets and water quality?

Climate change: How will a changing climate affect water availability?

Institutions: How can Latin America adapt to changing market forces and changing climate that impact agriculture, water, and human well-being?

Perspective:

- Integrated economies and societies
- The living resource base as the foundation for the integration
- Strengthening the ability of people to enhance Earth's life support capacity for societal development and human wellbeing



Make sustainable development possible

Slide courtesy of Carl Folke, Stockholm Resilience Center

How will we innovate, adapt, and transform to maintain human life support in a changing world?

A problem of managing social-ecological complexity.

Steve Carpenter
srcarpen@wisc.edu

University of Wisconsin
Center for Limnology

SARA(S)^2
Instituto Sudamericano de Ciencias de la Sustentabilidad y Resiliencia

South American Institute for Resilience and Sustainability Studies