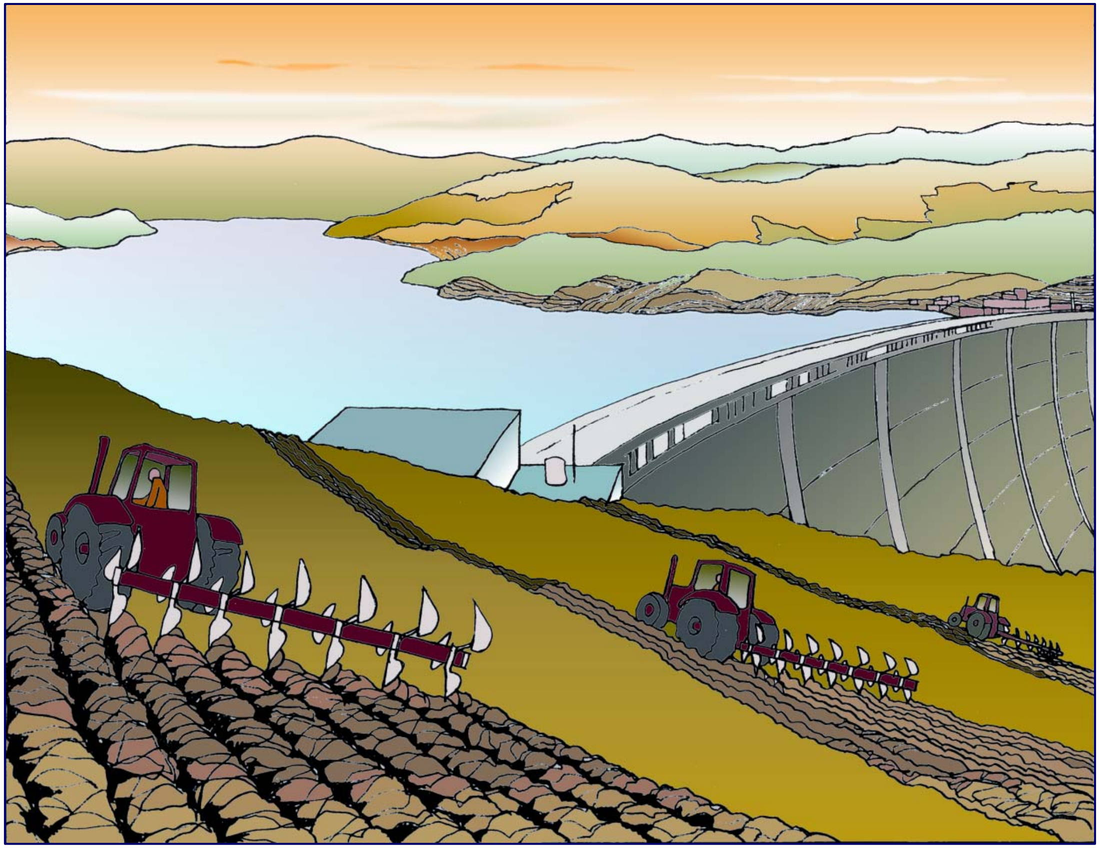
Land, Water and Climate Change Adaptation

Steve Carpenter (srcarpen@wisc.edu)



University of Wisconsin Center for Limnology
The Beijer Institute of Ecological Economics
LTER

Topics for the Talk:

Trends and links

Water withdrawals

Biogeochemical cycles

What could we do about it?

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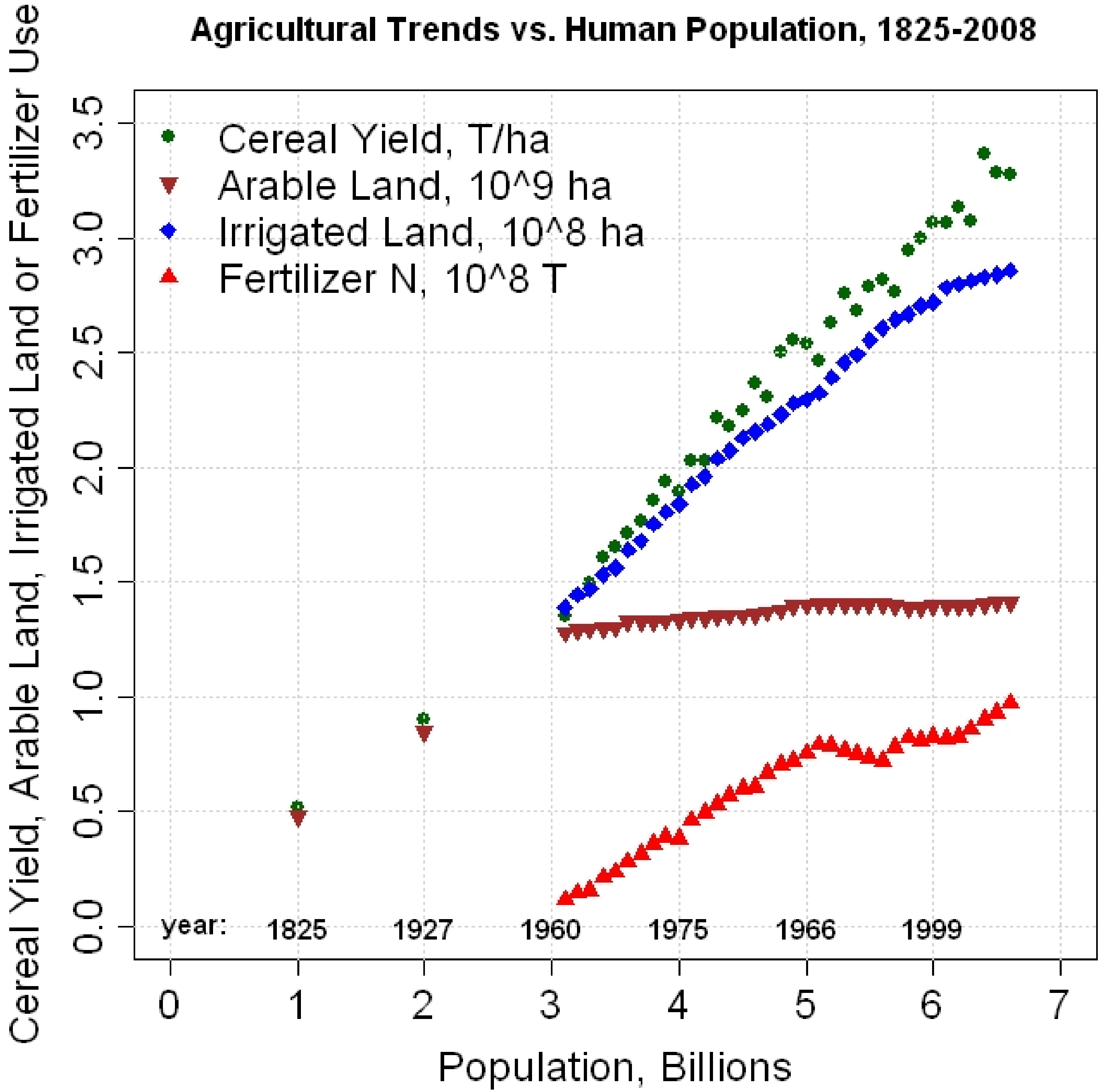
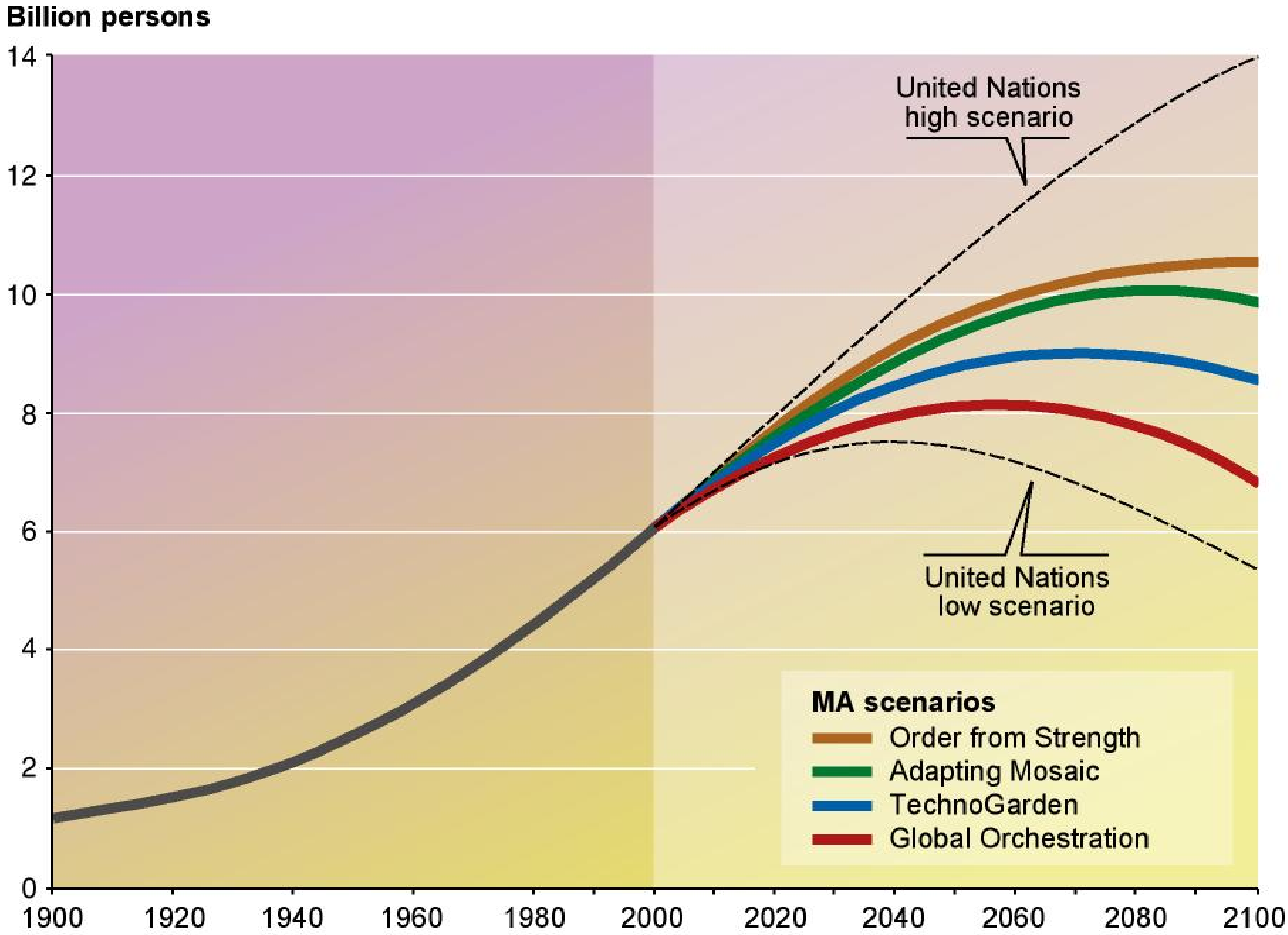


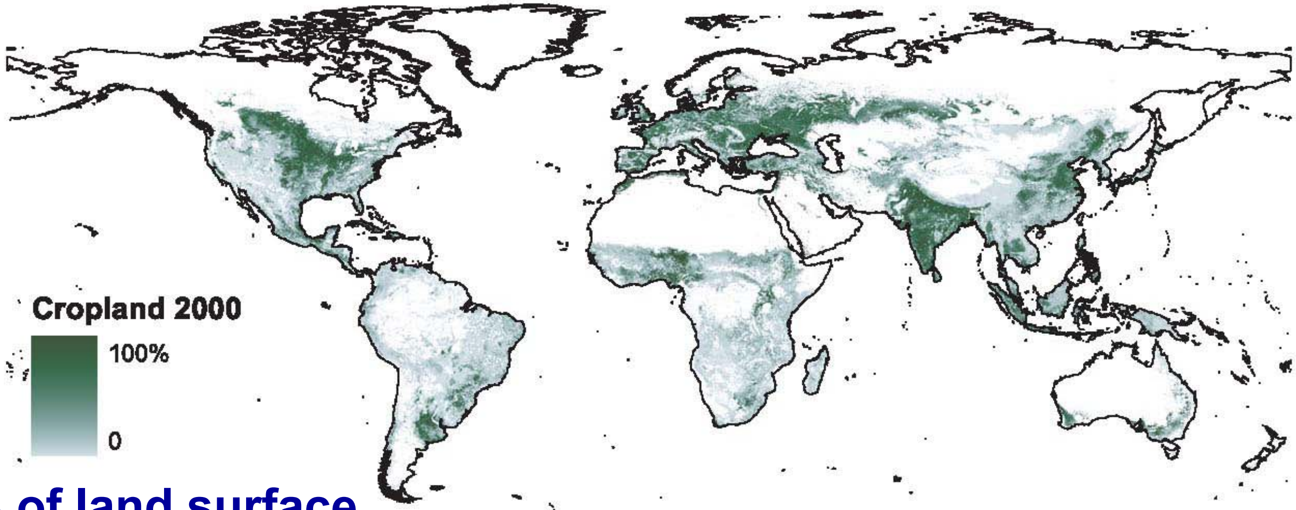
Cohen, J. 2002. Future of population. In: Cooper & Layard, *What the Future Holds*. MIT Press. Redrawn from Evans, 1998, *Feeding the Ten Billion*, Cambridge Univ. Press.
Updated to 2008 by J. Fabina and S. Carpenter using data from FAO and IFA.

Population Projections: MA Scenarios

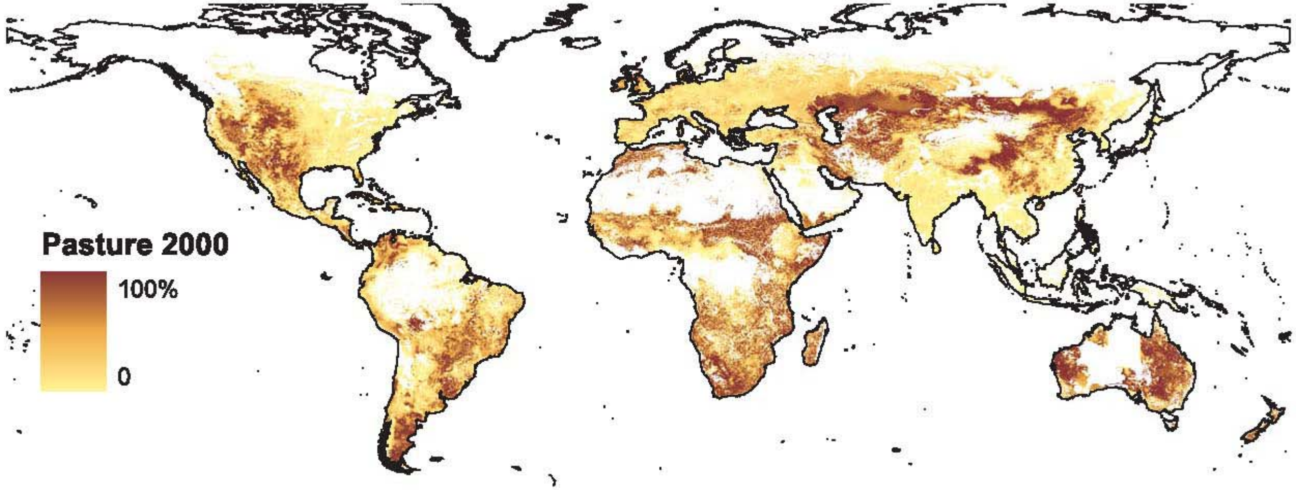


Source: Millennium Ecosystem Assessment

Agricultural Area

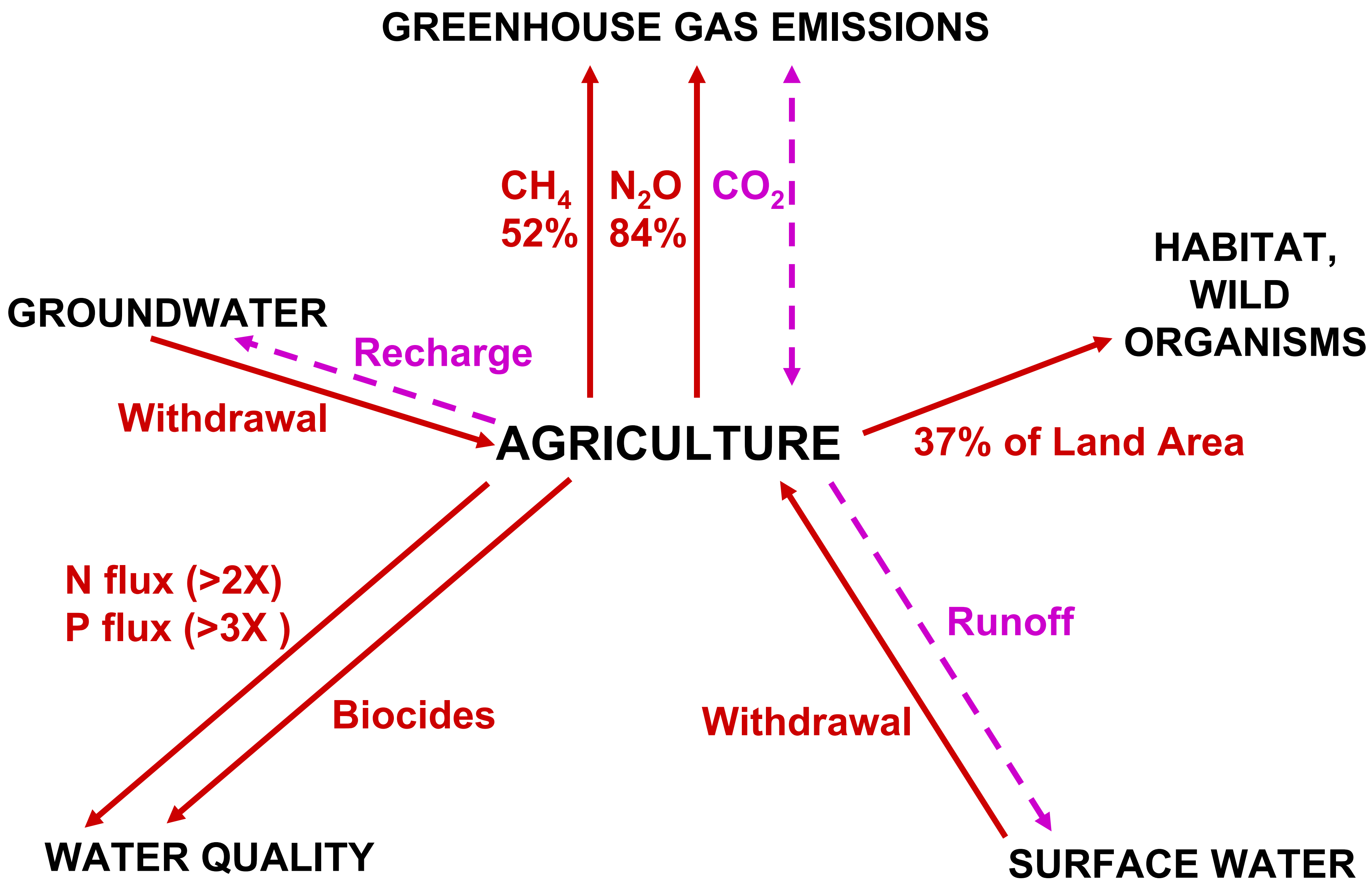


~13% of land surface



~24% of land surface

Ramankutty et al., 2008, Global Biogeochemical Cycles



GREENHOUSE GAS EMISSIONS
CH4 52%
N2O 84%
CO2
GROUNDWATER
Recharge
Withdrawal
AGRICULTURE
HABITAT, WILD ORGANISMS
37% of Land Area
N flux (>2X)
P flux (>3X)
Biocides
Runoff
Withdrawal
WATER QUALITY
SURFACE WATER

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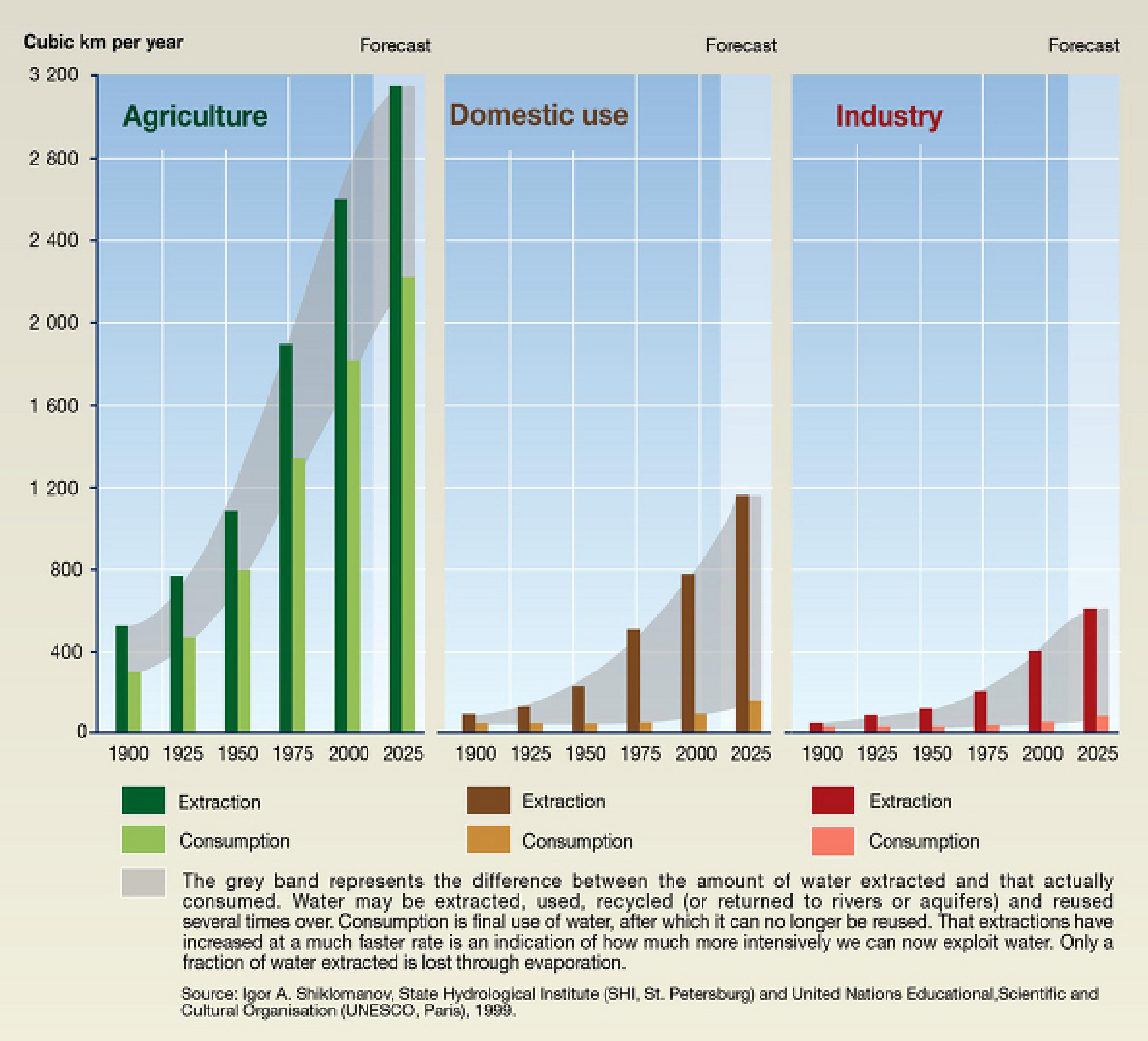
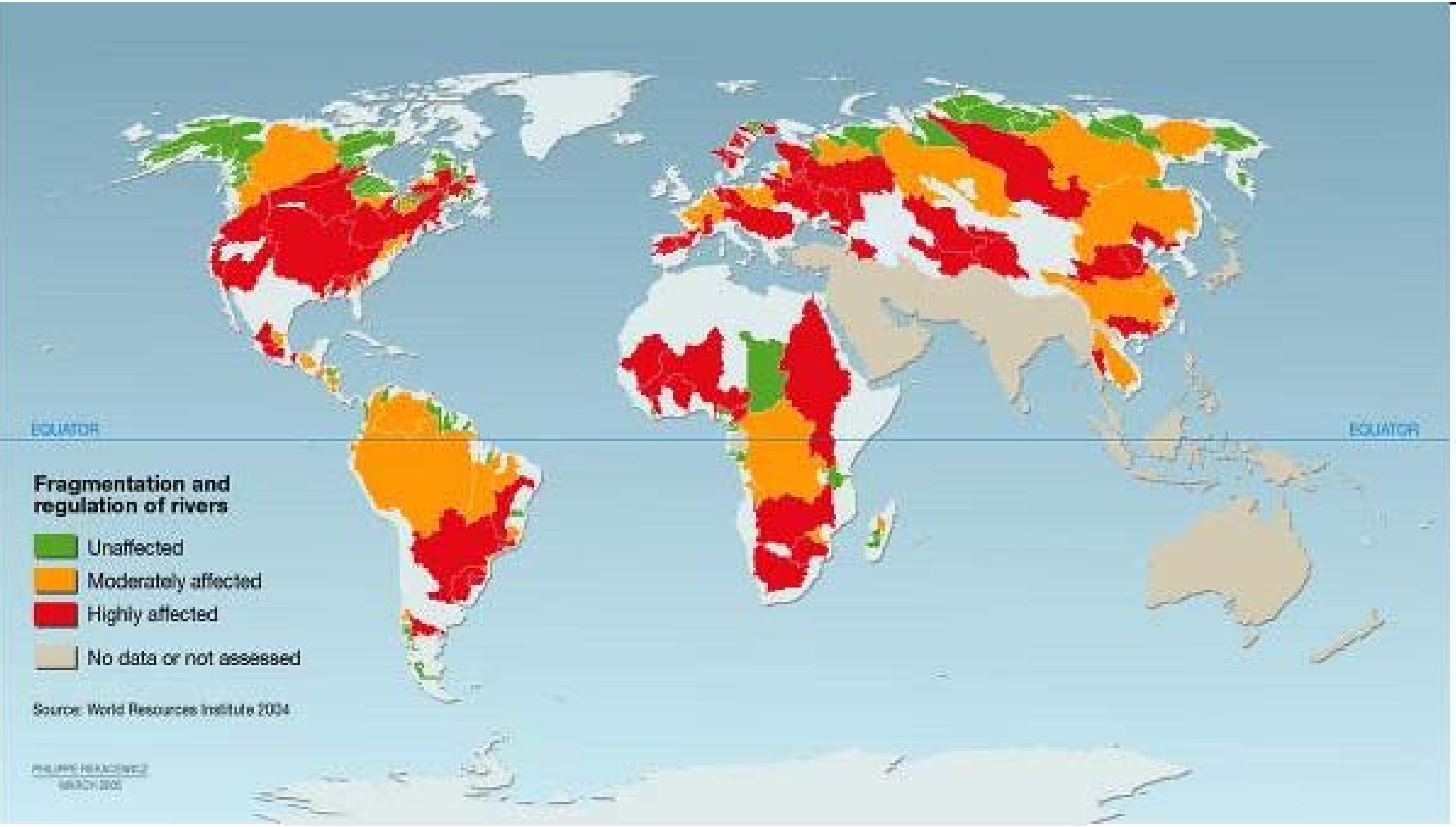
Global International Water Assessment
http://www.grida.no/publications/vg/water2/



River Fragmentation & Habitat for Aquatic Organisms



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

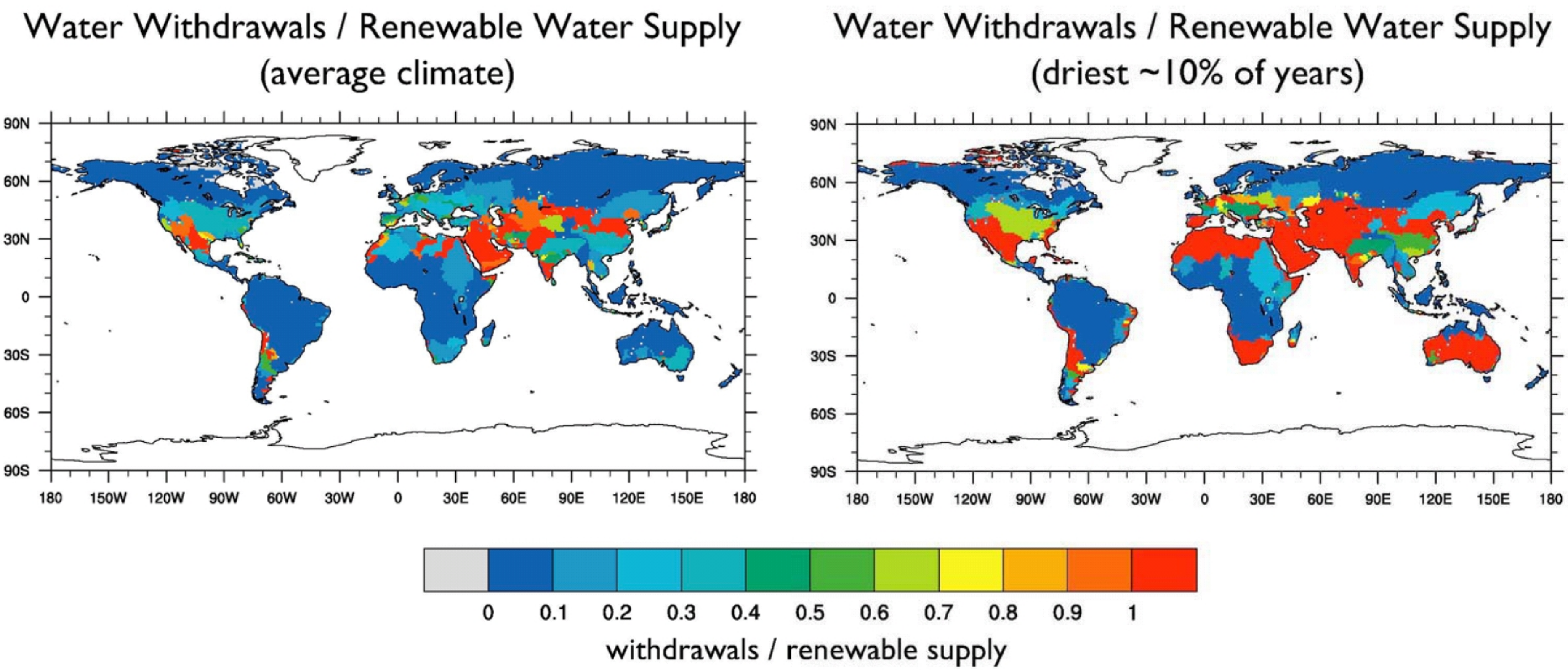
High-population countries: China 6.5%, India 43%

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



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

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Human-Driven Changes in Biogeochemical Cycles

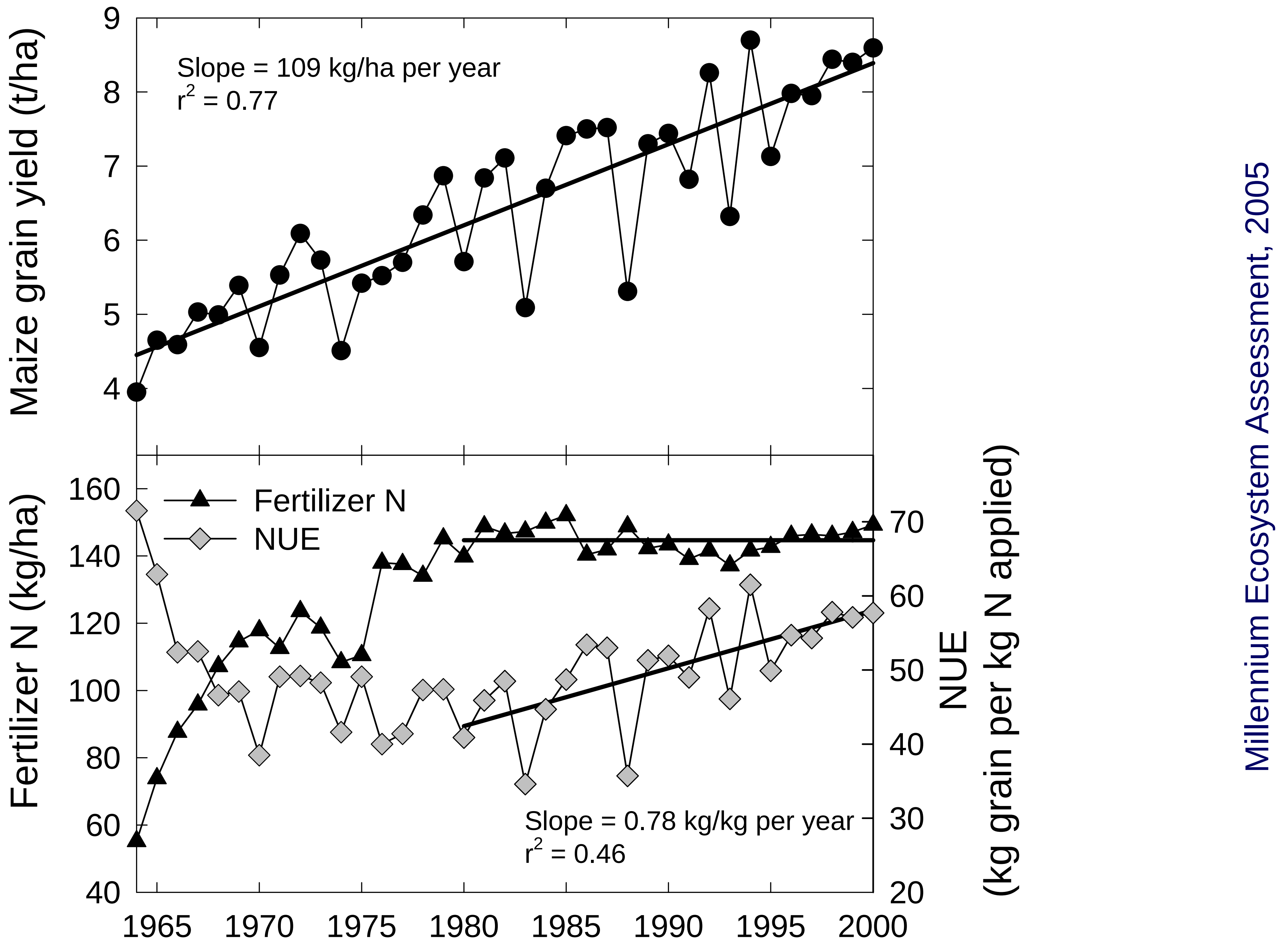
Element	Natural Flux (10^6 MT/year	Human Flux (10^6 MT/year	% Change from Human Activity	Explanation
C	61,000	8,000	+13	Terrestrial total respiration; Fossil fuel and land use C
N	130	140	+108	Natural biological fixation; Fertilzers, combustion, rice
P	12.5	18.5	+248	Weathering; Mining
S	80	90	+113	Natural 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

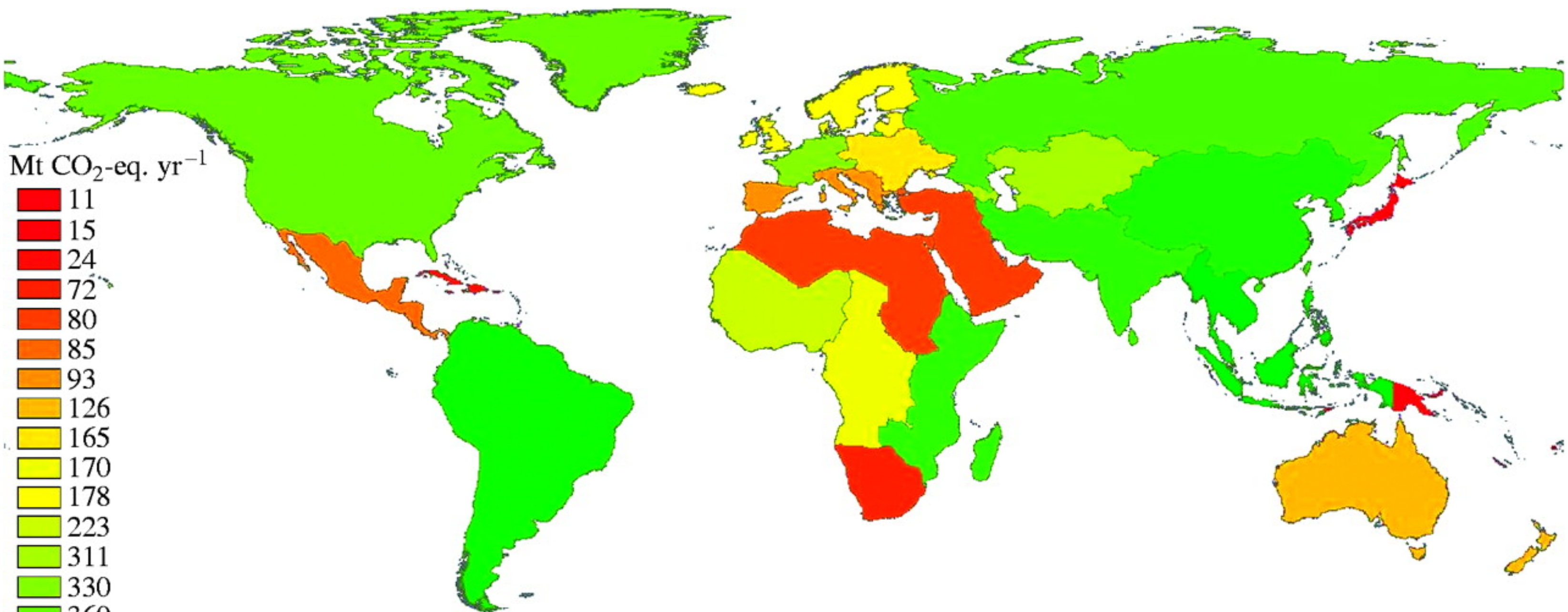
Red tide, Maine, USA

Cyanobacteria, Chaohu Lake, China



Maize grain yield (t/ha)
Slope = 109 kg/ha per year
r^2 = 0.77
Fertilizer N (kg/ha)
Fertilizer N
NUE
Slope = 0.78 kg/kg per year
r^2 = 0.46
NUE
(kg grain per kg N applied)
1965
1970
1975
1980
1985
1990
1995
2000
Millennium Ecosystem Assessment, 2005

Total biophysical mitigation potentials (all practices, all GHGs: Mt CO2-eq.yr−1) for each region by 2030, showing mean estimates (B1 scenario shown though the pattern is similar for all SRES scenarios).



Global GHG Offsets by Agriculture, % of Emissions:

- 5% at $20 / ton CO_2-eq
- 9% at $50 / ton CO_2-eq
- 14% at $100 / ton CO_2-eq
- 20% at full biophysical potential

N

Smith P et al. Phil. Trans. R. Soc. B 2008;363:789-813

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

Greenhouse Gases and Agriculture – Mitigation Options

Perennial crops, extended rotations, cover crops

Match N applications to crop uptake

Reduce tillage, retain crop residues

Manage irrigation to maximize C storage in soil

Adjust grazing rates to maximize C storage in soil

Manage ruminant diet & genetics to decrease CH_4 emission

Manage manure (digestors)

Etc.

Smith P et al. Phil. Trans. R. Soc. B 2008;363:789-813

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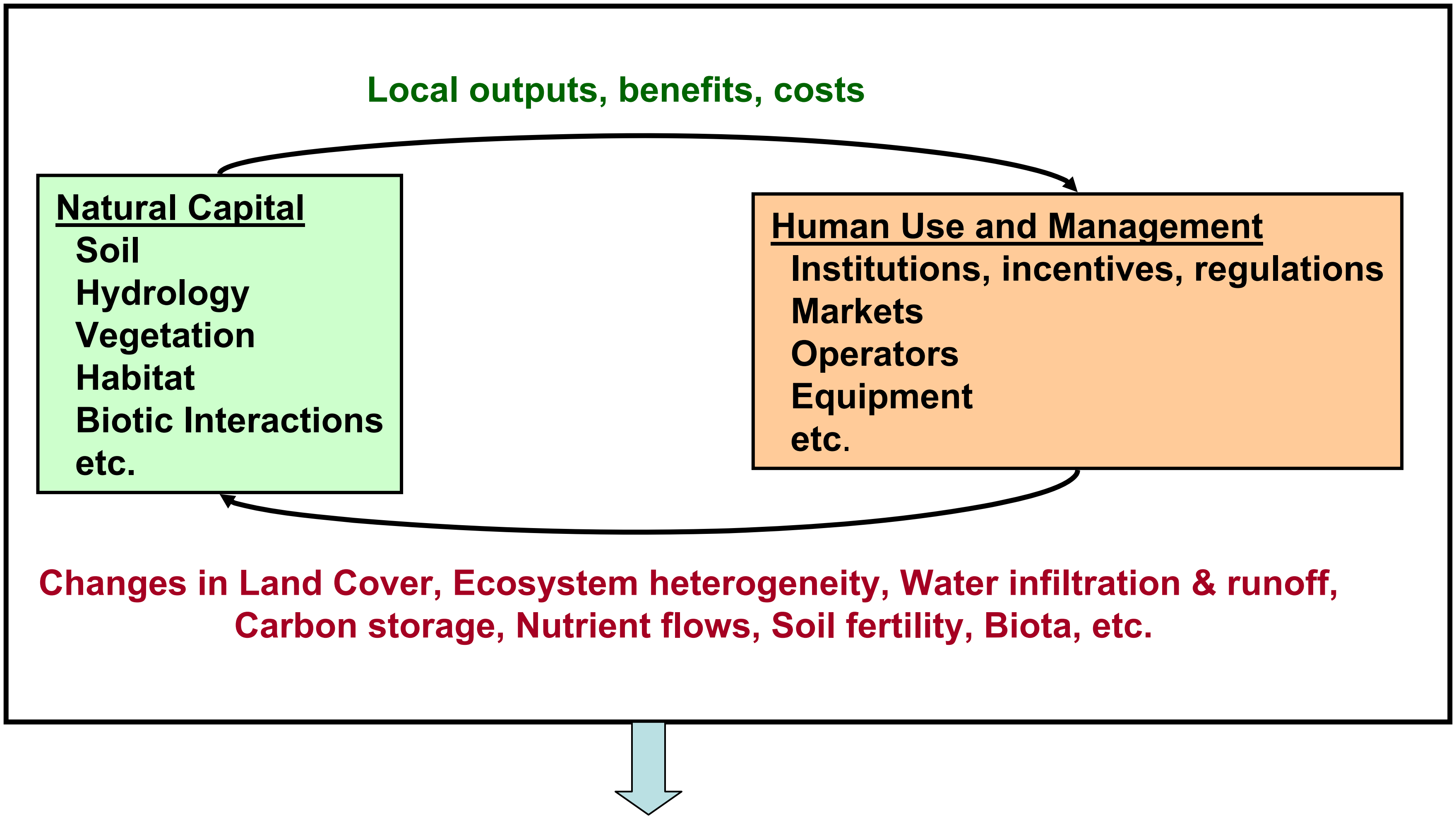
What Could We Do About It?

"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

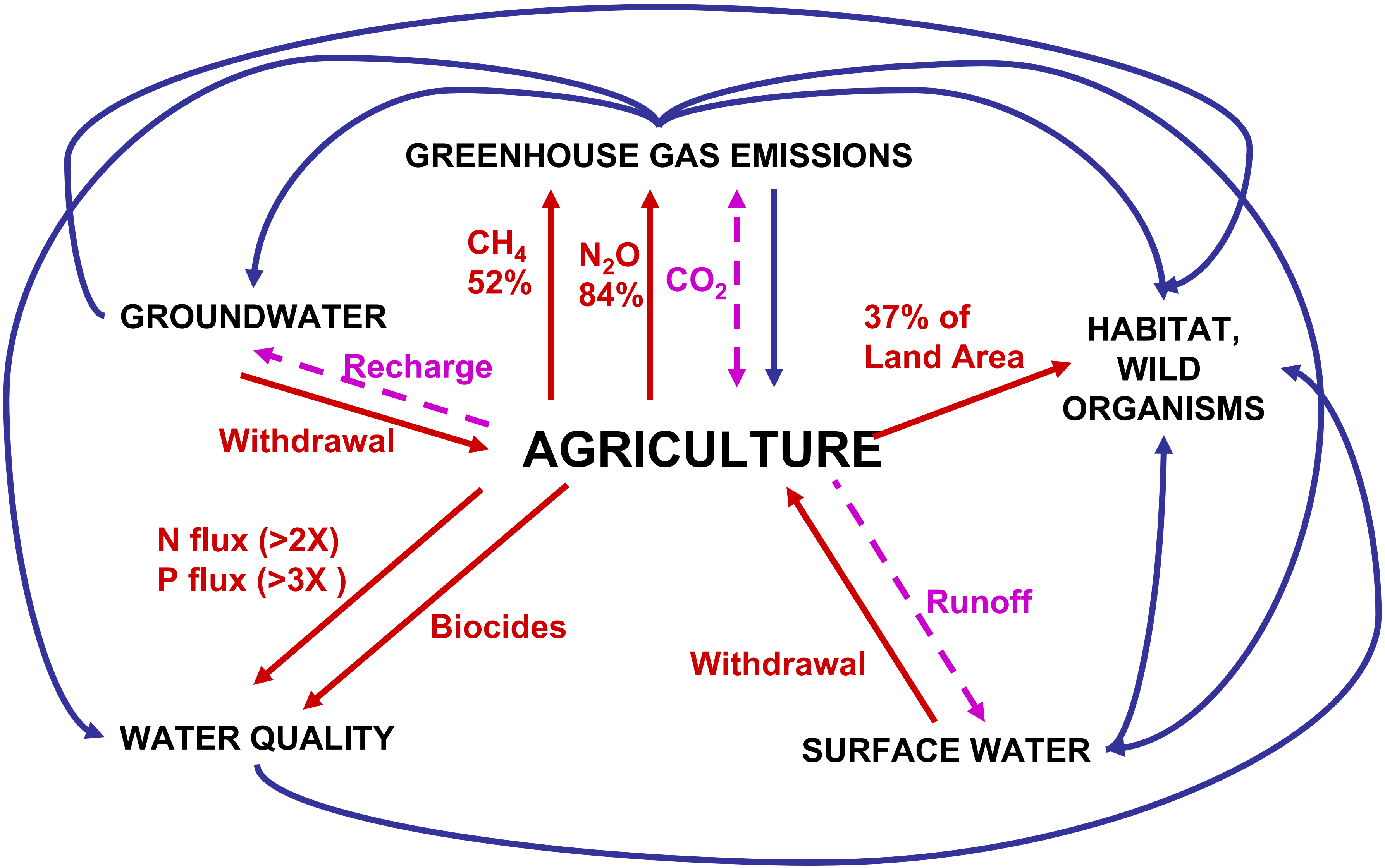
Create a Global Pattern of Local Innovation

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.

Terraced rice in China, from Dybas, 2009, BioScience 640-646.

CONCLUSIONS:

Key Connections: Water, Agriculture, Climate and Biota



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

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This requires new interdisciplinary work:

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

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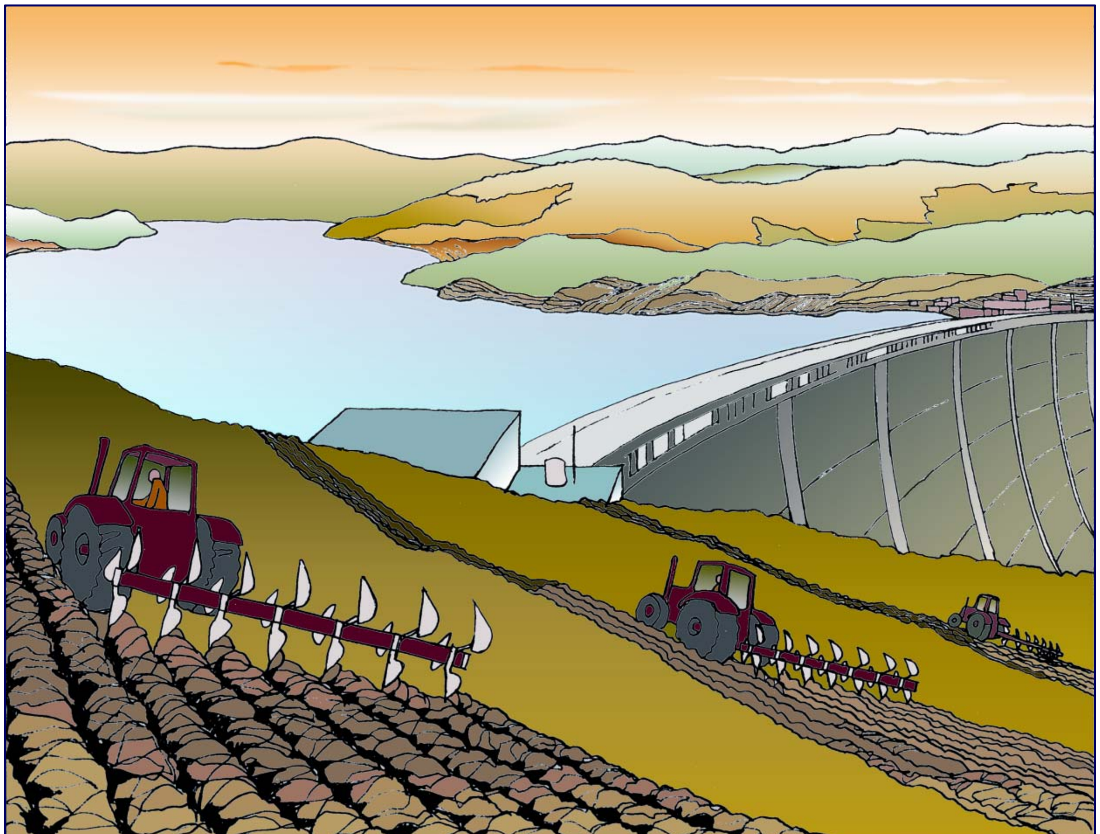

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