Manure Happens: The Consequences of Feeding Seven Billion Human Omnivores

Eric A. Davidson

July 25, 2017

Fifth International Conference on Nitrification and Related Processes

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
APPALACHIAN LABORATORY

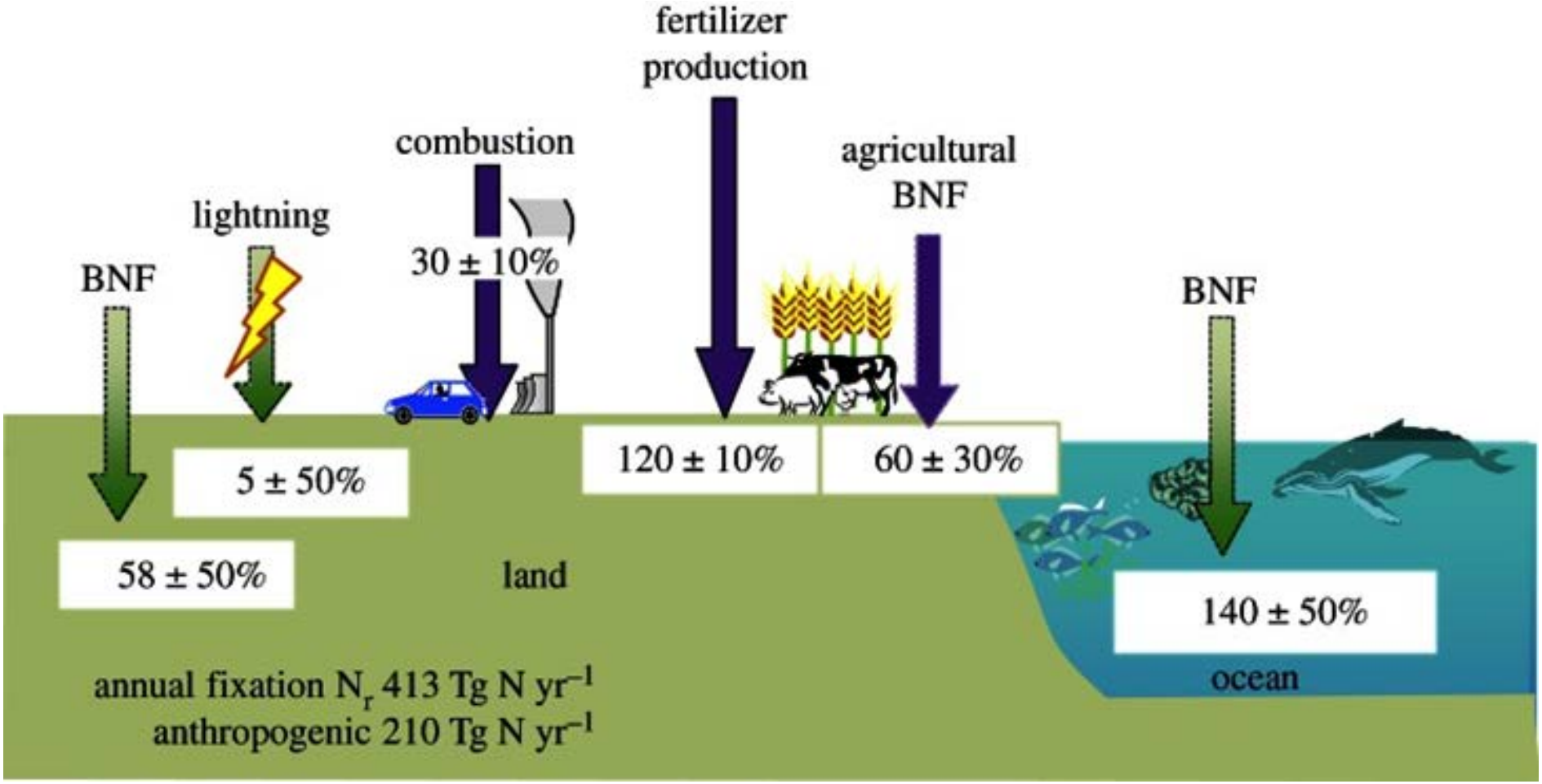


Figure 1. Global nitrogen fixation, natural and anthropogenic in both oxidized and reduced forms through combustion, biological fixation, lightning and fertilizer and industrial production through the Haber–Bosch process for 2010. The arrows indicate a transfer from the atmospheric N_2 reservoir to terrestrial and marine ecosystems, regardless of the subsequent fate of the N_r. Green arrows represent natural sources, purple arrows represent anthropogenic sources.

Fowler et al. 2013 The global nitrogen cycle in the twenty-first century. Phil Trans R Soc B 368: 20130164

nature Vol 461|24 September 2009

FEATURE

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue **Johan Rockström** and colleagues.

NATURE|Vol 461|24 September 2009
"Editor's note Please note that this Feature and the Commentaries are not peer-reviewed research. This Feature, the full paper and the expert Commentaries can all be accessed from http://tinyurl.com/planetboundaries."

Updated by Steffen et al. 2015. Science

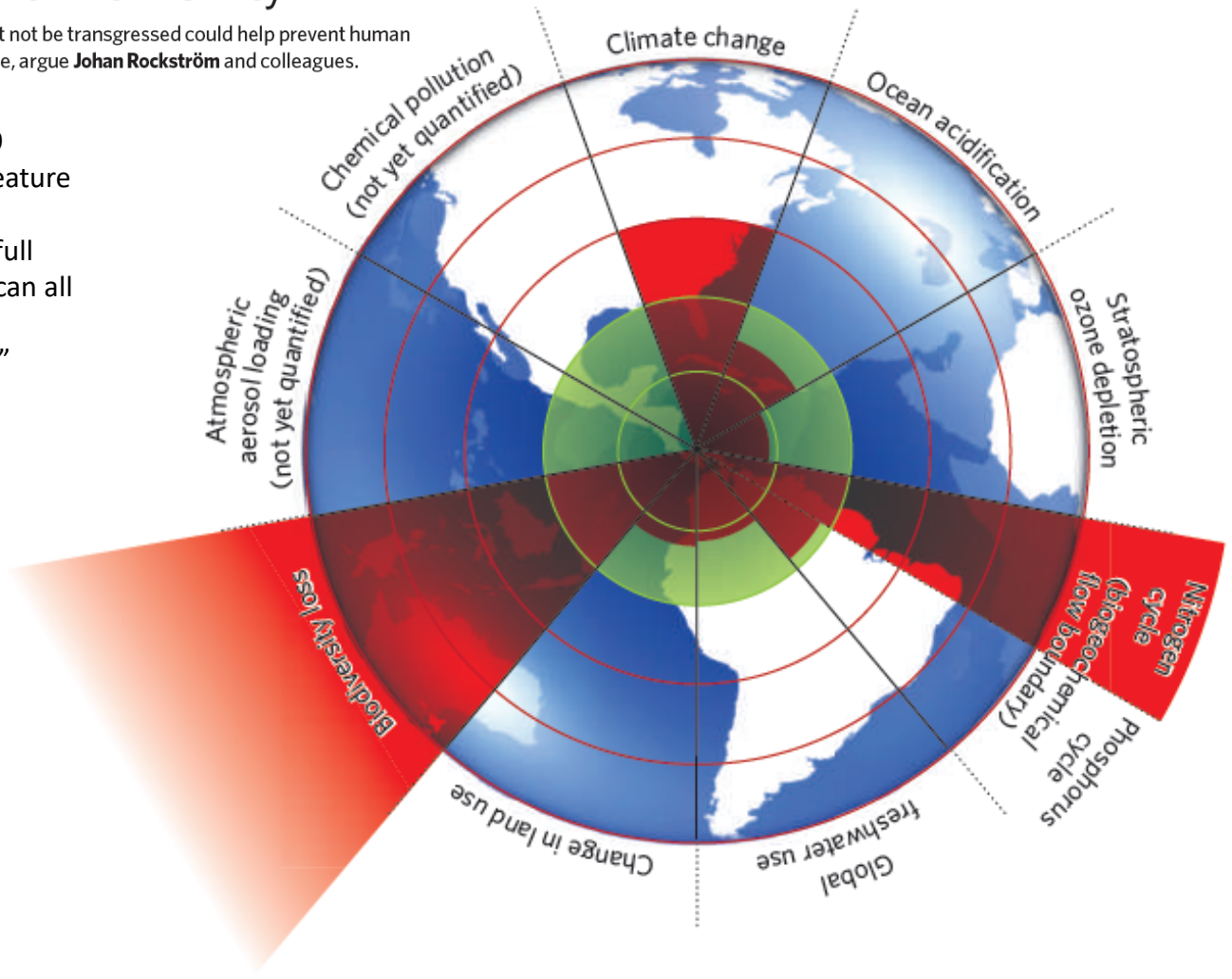
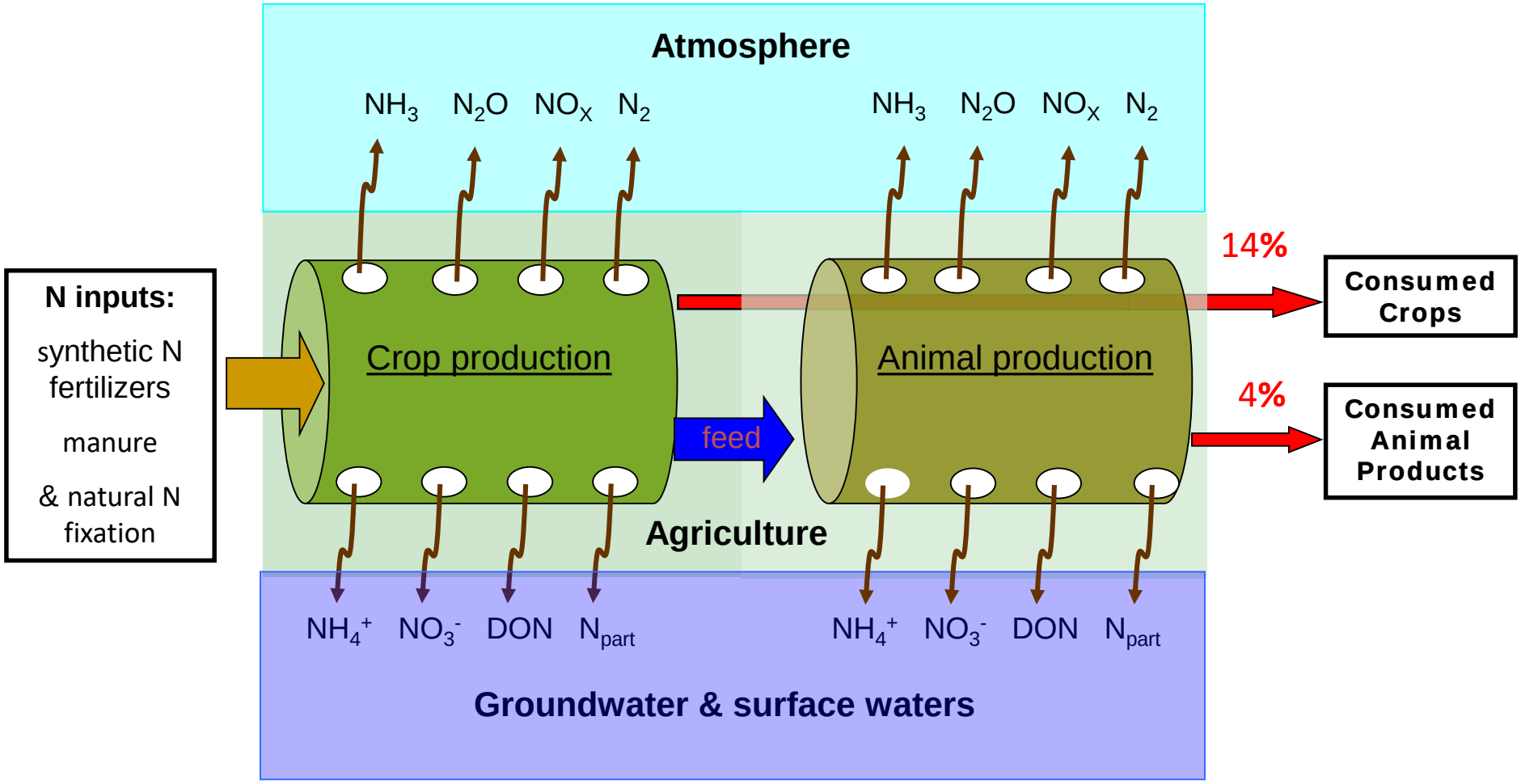


Figure 1 | Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

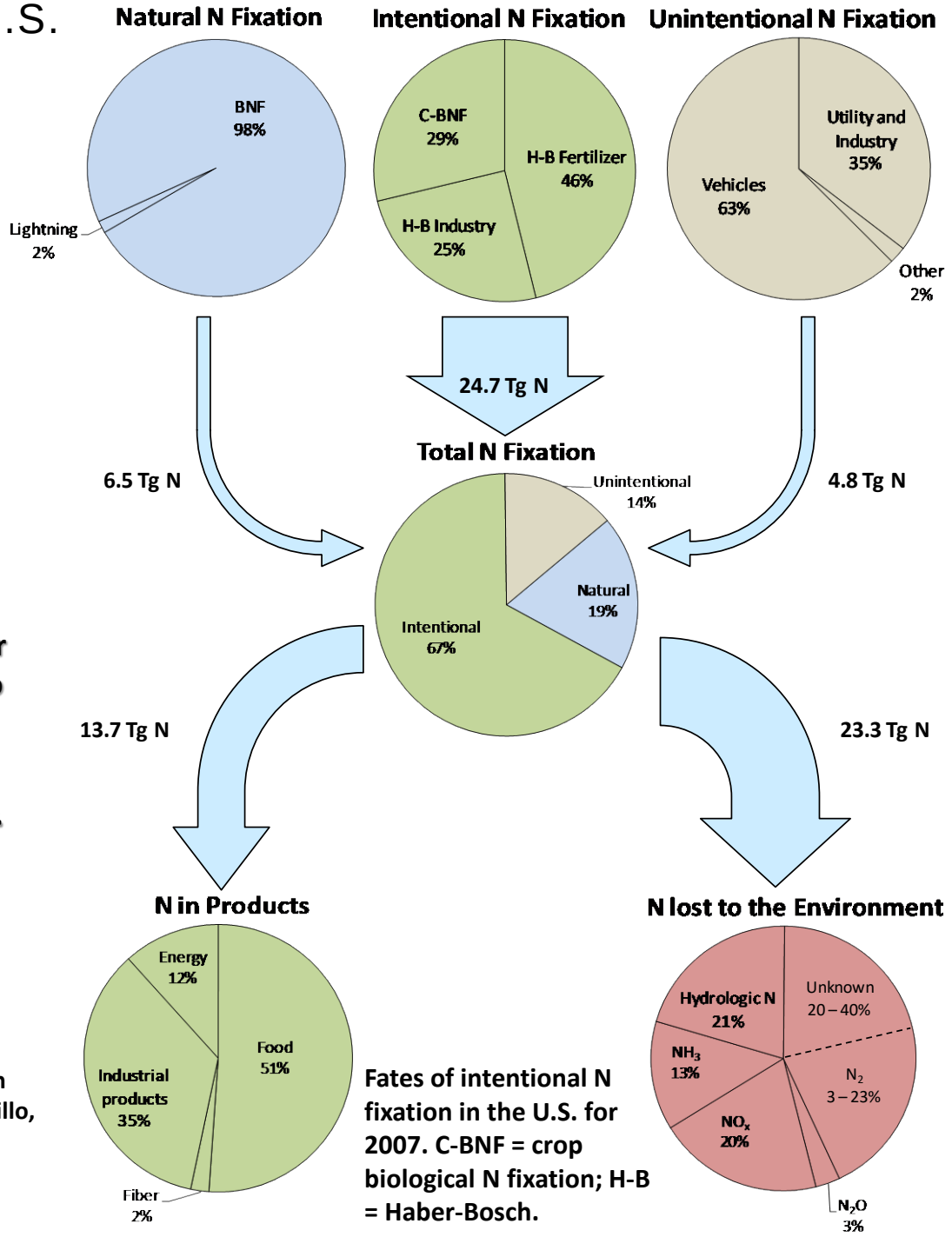
Nitrogen: A Very Leaky Element



Oenema et al. 2009. Agriculture, Ecosystems & Environment, 133, 280-288.

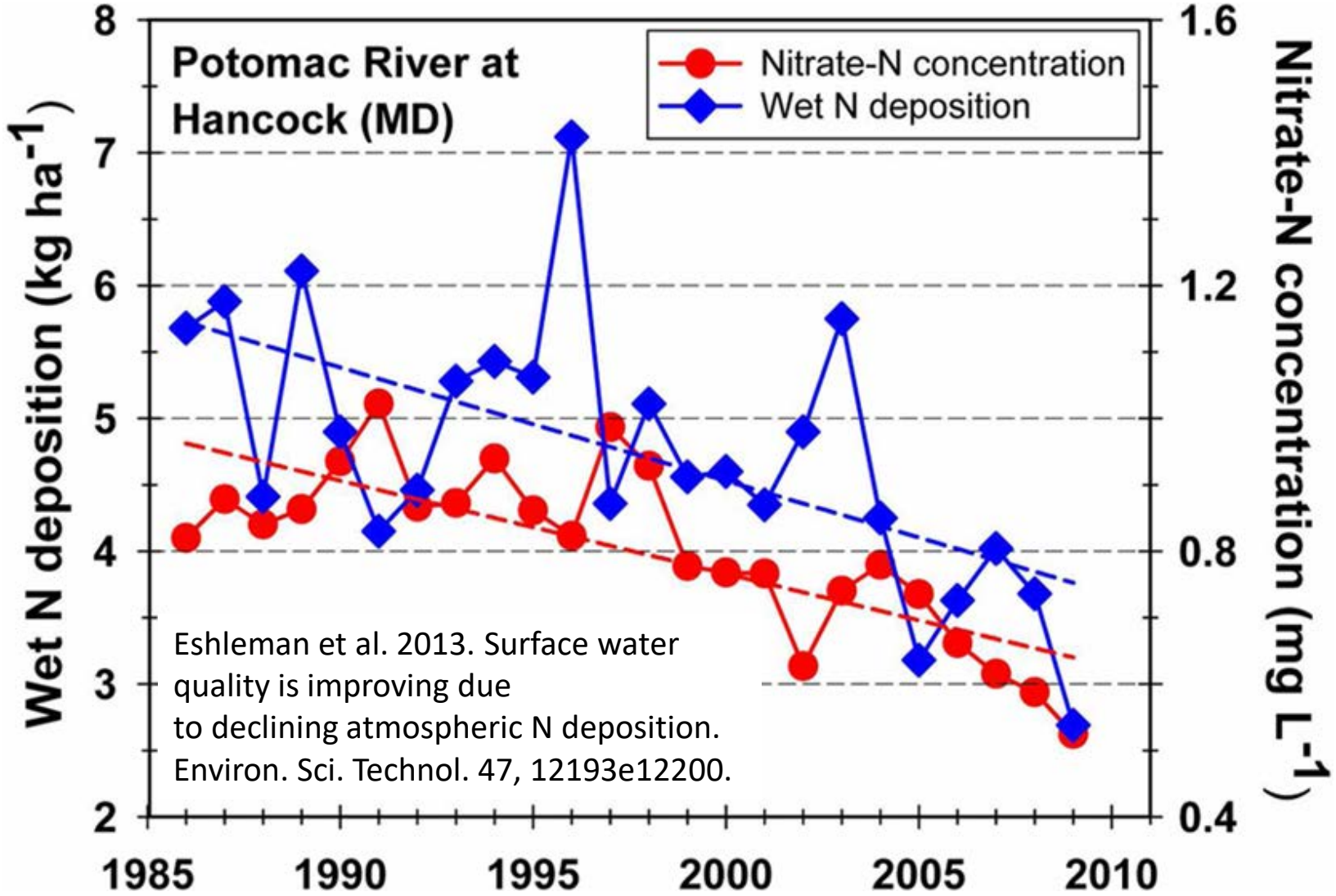
Alteration of N Flows in the U.S.

- **Intentional Nr creation accounts for 2/3^{rds} of total N_2 fixation in the U.S.**
- **Nearly 2/3^{rds} of unintentional Nr is from vehicle use, while a majority of the remainder is from stationary power plants and industrial boilers.**
- **About 3/4^{ths} of intentional Nr enters US agricultural systems. Synthetic fertilizer comprises 2/3^{rds} of Nr input to U.S. agriculture, with the remainder originating from C-BNF. Industrial products like nylon and explosives account for the remaining 25% of intentionally fixed Nr in the U.S.**
- **About 1/3rd of total Nr is incorporated into products, about 1/3rd is lost as Nr to the broader environment, about 1/3rd is denitrified or lost to unknown sinks.**
- **Nitrogen use efficiency is about 38% for agriculture and about 55% for all intentional Nr.**



Fates of intentional N fixation in the U.S. for 2007. C-BNF = crop biological N fixation; H-B = Haber-Bosch.

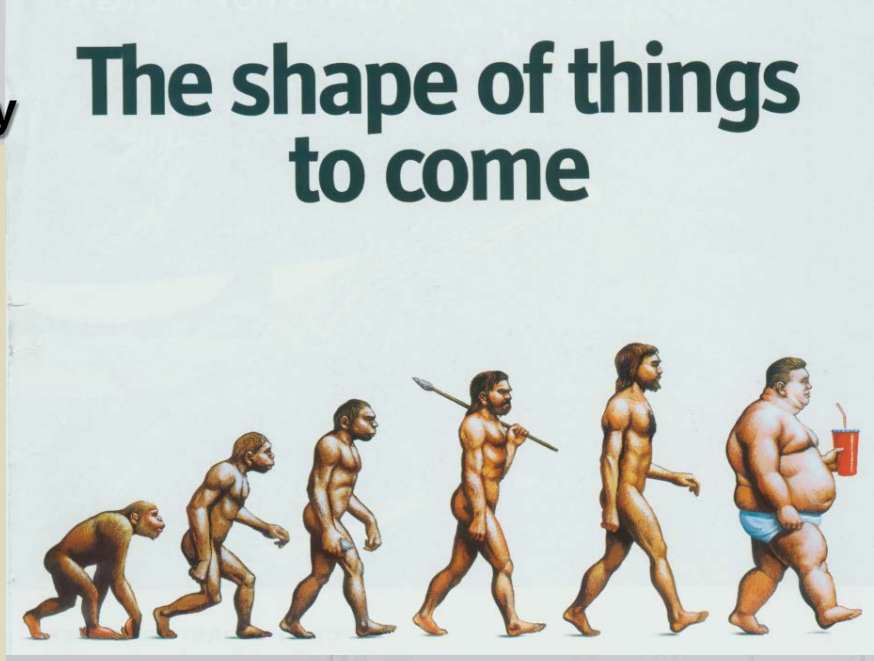
From chapter by Benjamin Z. Houlton, Elizabeth Boyer, Adrien Finzi, James Galloway, Allison Leach, Daniel Liptzin, Jerry Melillo, Todd S. Rosenstock, Dan Sobota, and Alan R. Townsend
Biogeochemistry (2013) 114:11-23



"These unanticipated region-wide water quality benefits can be attributed to NOx emission controls brought about by the 1990 Clean Air Act Amendments (and subsequent U.S. NOX control programs) and reflect a water quality "success story" in the Chesapeake Bay restoration" : Eshleman et al. 2016. Atmospheric Environment (2016), http://dx.doi.org/10.1016/j.atmosenv.2016.07.004

The Haber-Bosch process is one of the greatest public health boons in human history

- **Eutrophication of estuaries; dead zones; harmful algal blooms**
- **Nitrate in drinking water**
- **NOx, O_3, and PM2.5 air pollution**
- **N_2O as greenhouse gas & stratospheric ozone reactant**
- **Acid rain & biodiversity loss**



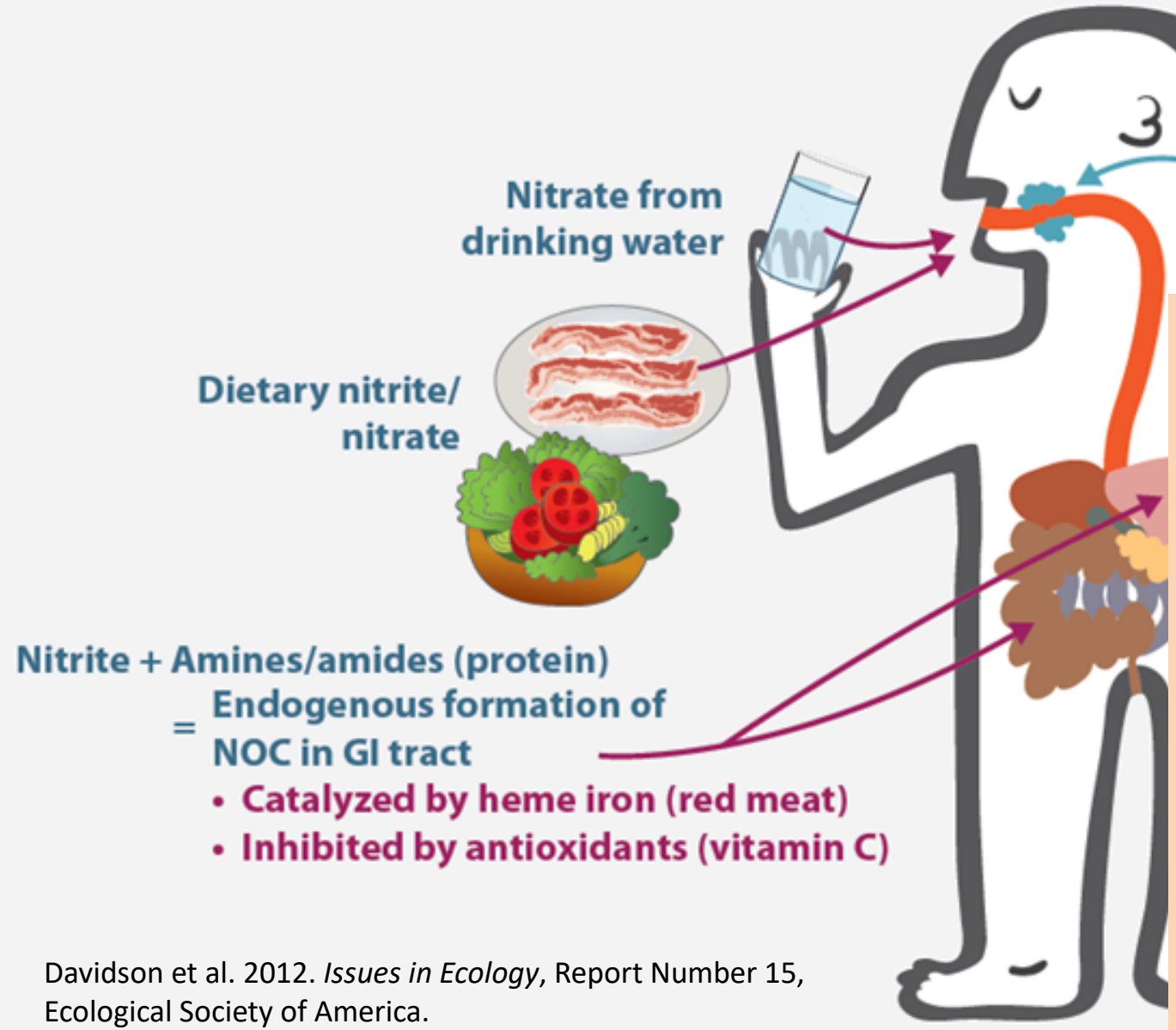
Drinking Water Nitrate

- U.S. standard of 10 ppm
- In place because of methylglobinemia

Methemoglobinemia
"blue baby syndrome"

- The need for maintaining the standard is a matter of recent controversy

Nitrate and nitrite from drinking water and diet can form N-nitroso compounds in the stomach and colon.



WHO International Agency for Research on Cancer expert working group:

- **"ingested nitrate or nitrite under conditions that result in endogenous nitrosation is probably carcinogenic to humans"**
- **NOCs are potent carcinogens and teratogens in animals including non-human primates.**

Davidson et al. 2012. *Issues in Ecology*, Report Number 15, Ecological Society of America.

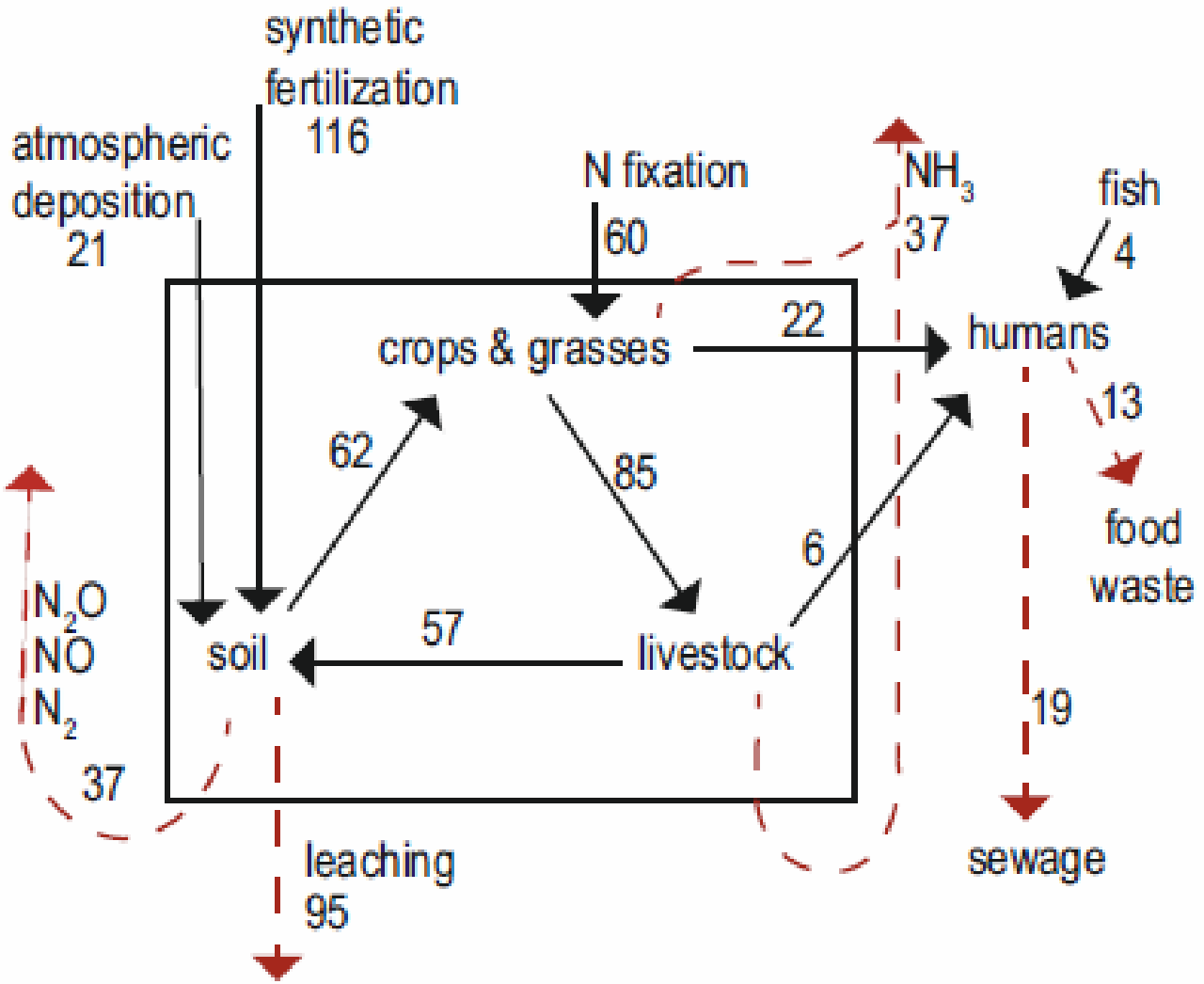
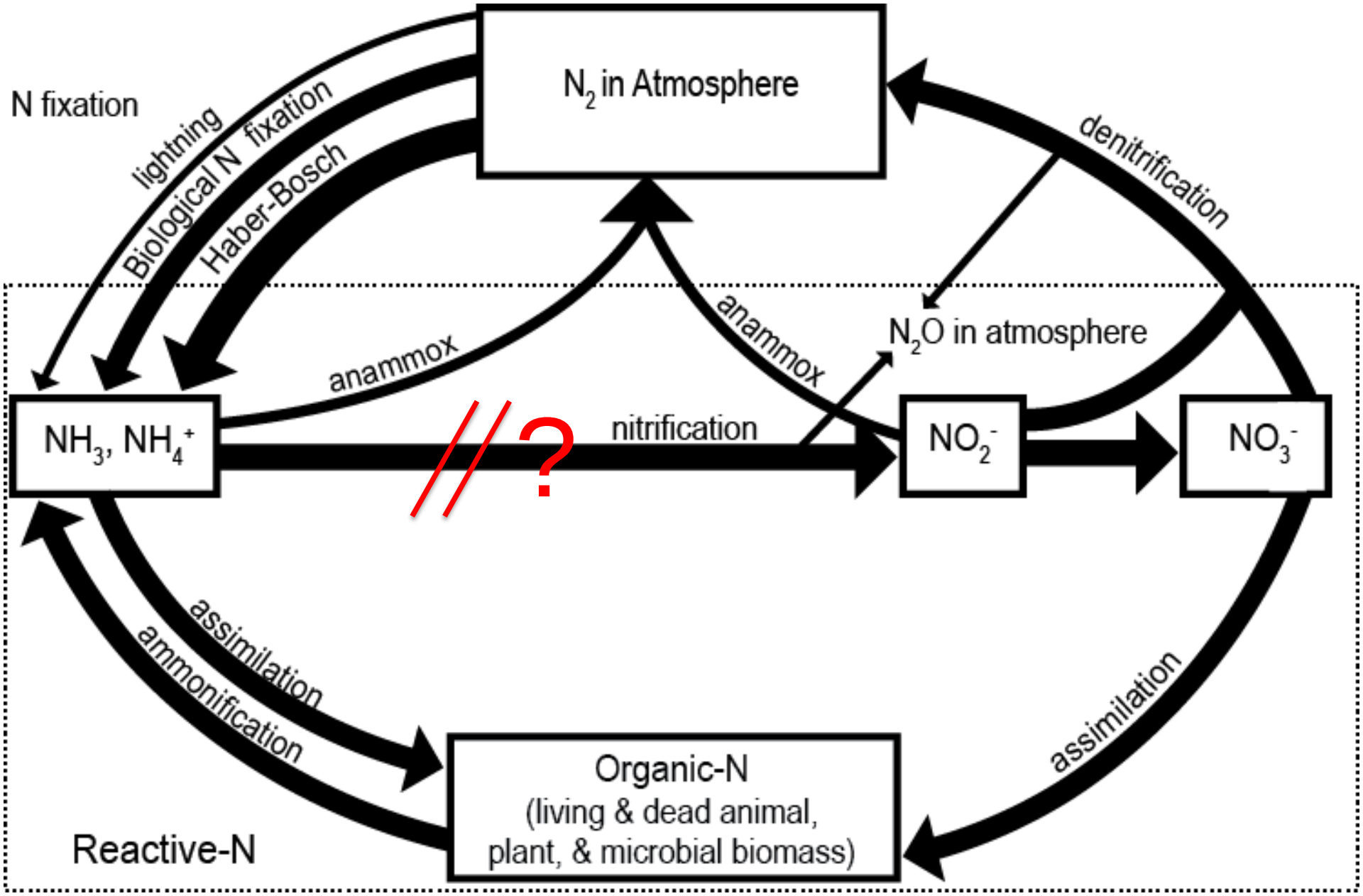
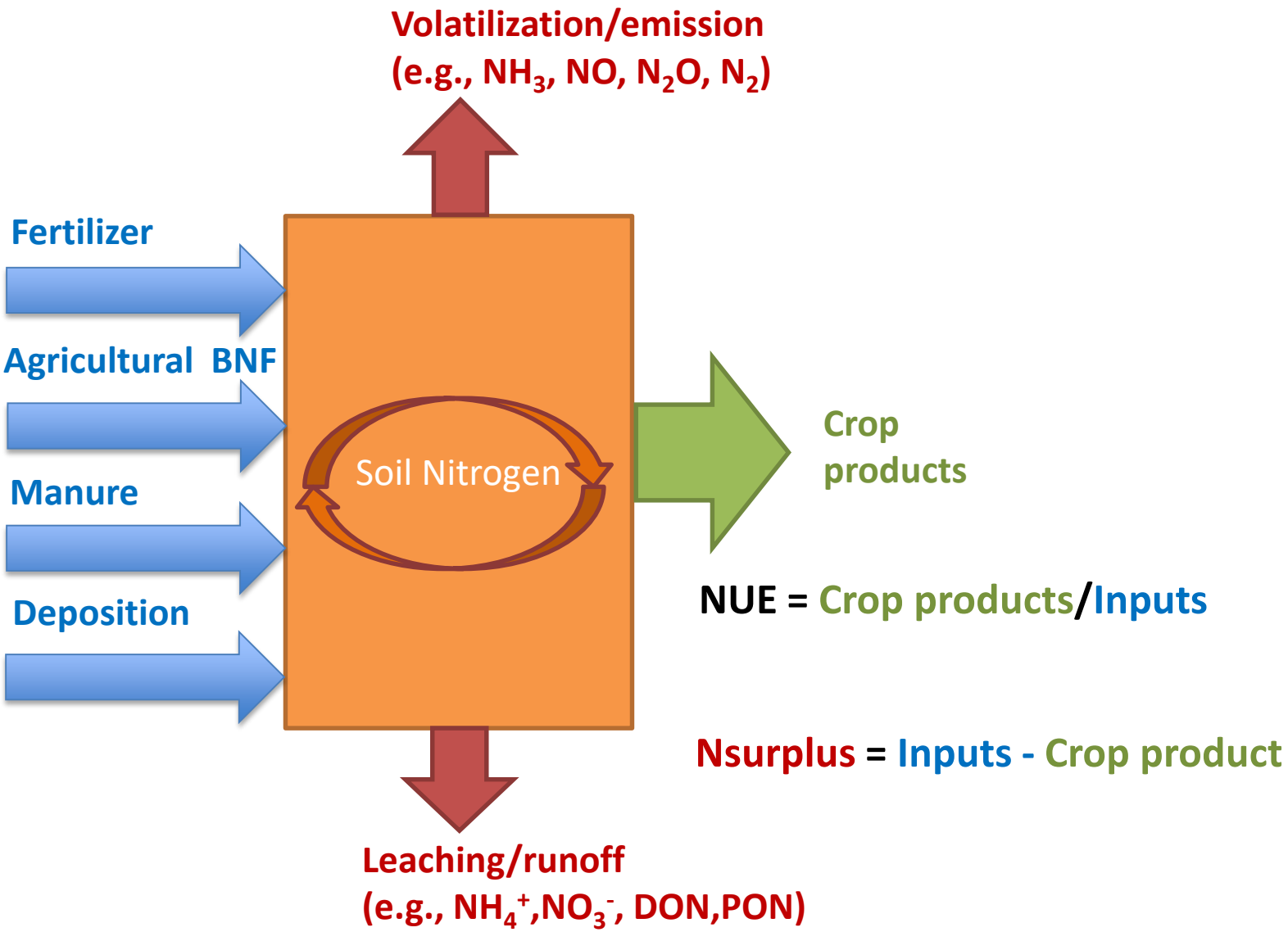


Fig. 2 Estimated annual N budget for global agriculture (based on estimates in Bodirsky et al. 2014, Sutton et al. 2013) Loss pathways are shown as *red-dashed lines* while input and transfer pathways are depicted as *black solid lines* (color figure online)

Davidson et al. 2016. J. Environ. Studies Science

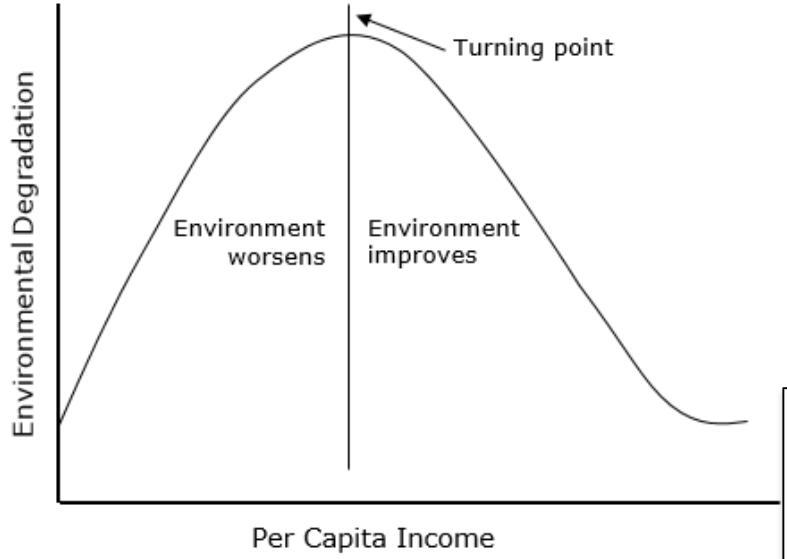


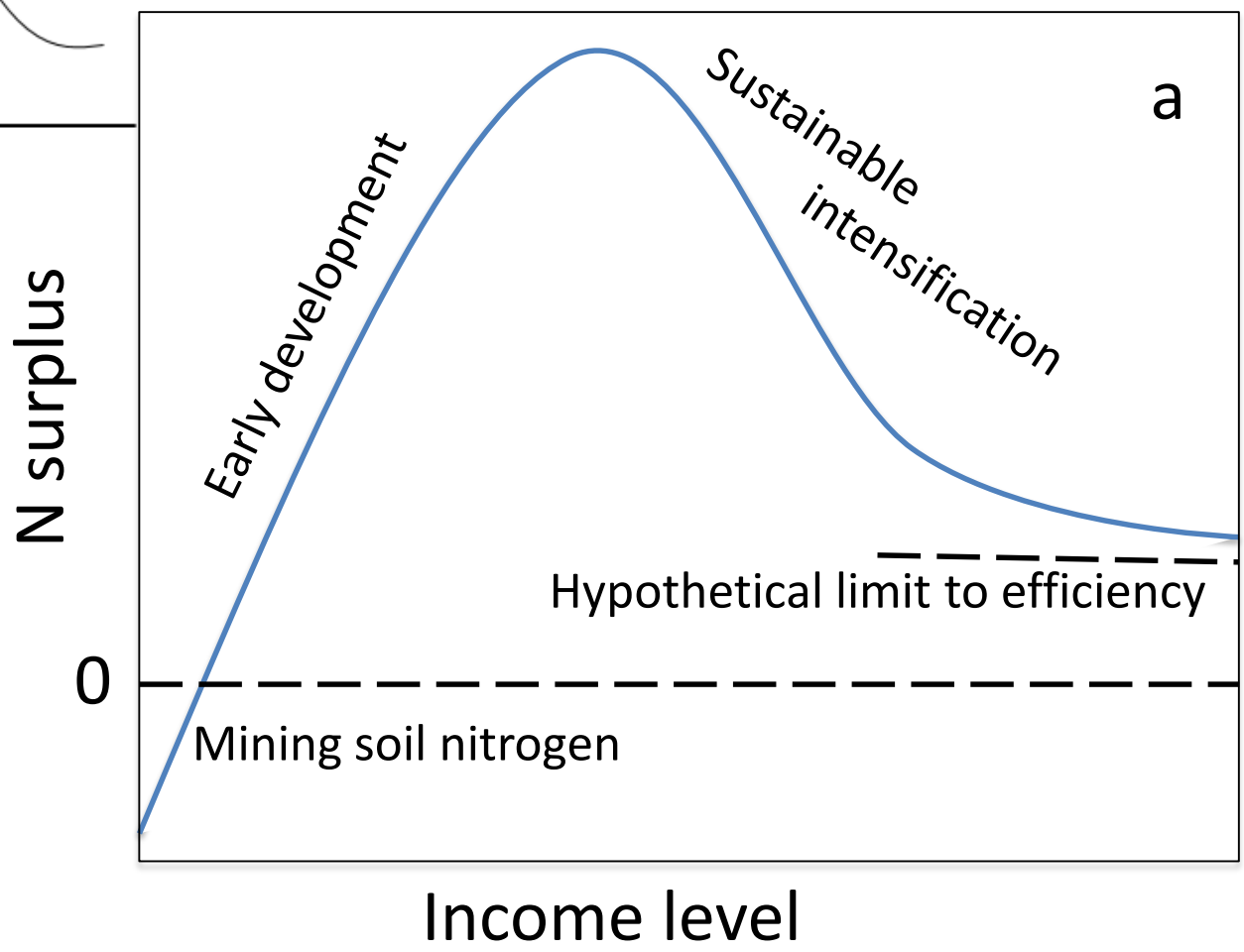
Davidson et al. 2016. J. Environ. Studies Science



Zhang et al. 2015. Nature 528:51-59

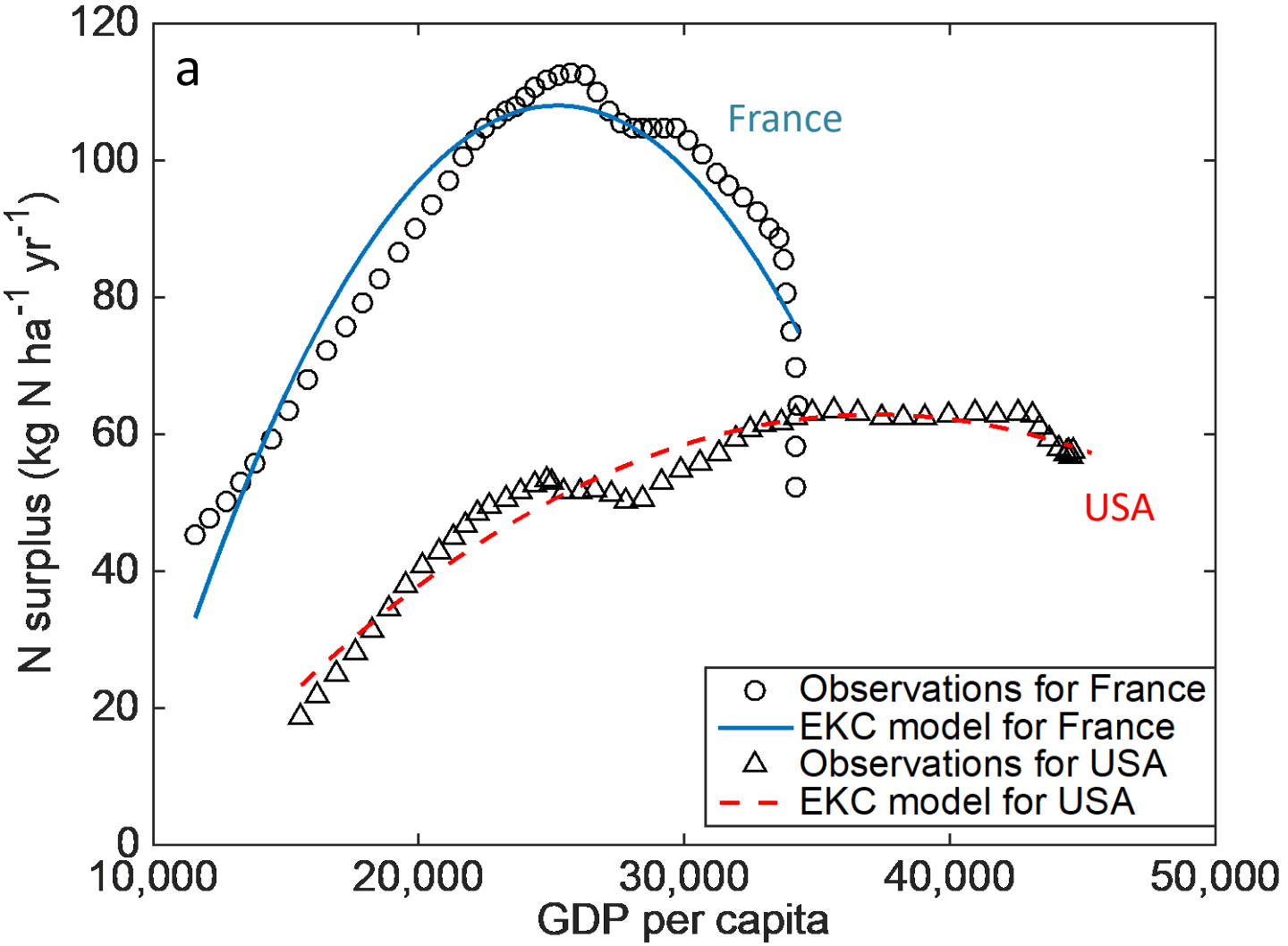
The Environmental Kuznets Curve



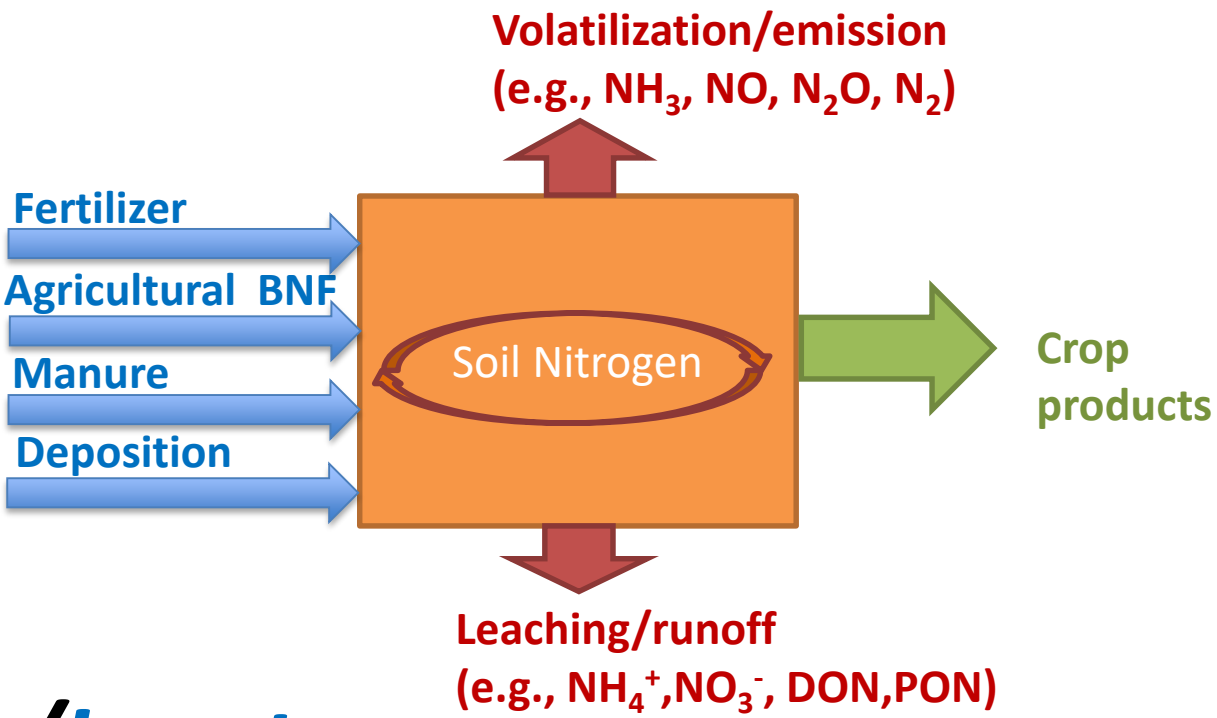


Zhang et al. 2015. Nature 528:51-59

N surplus follows the EKC model for western Europe and North America



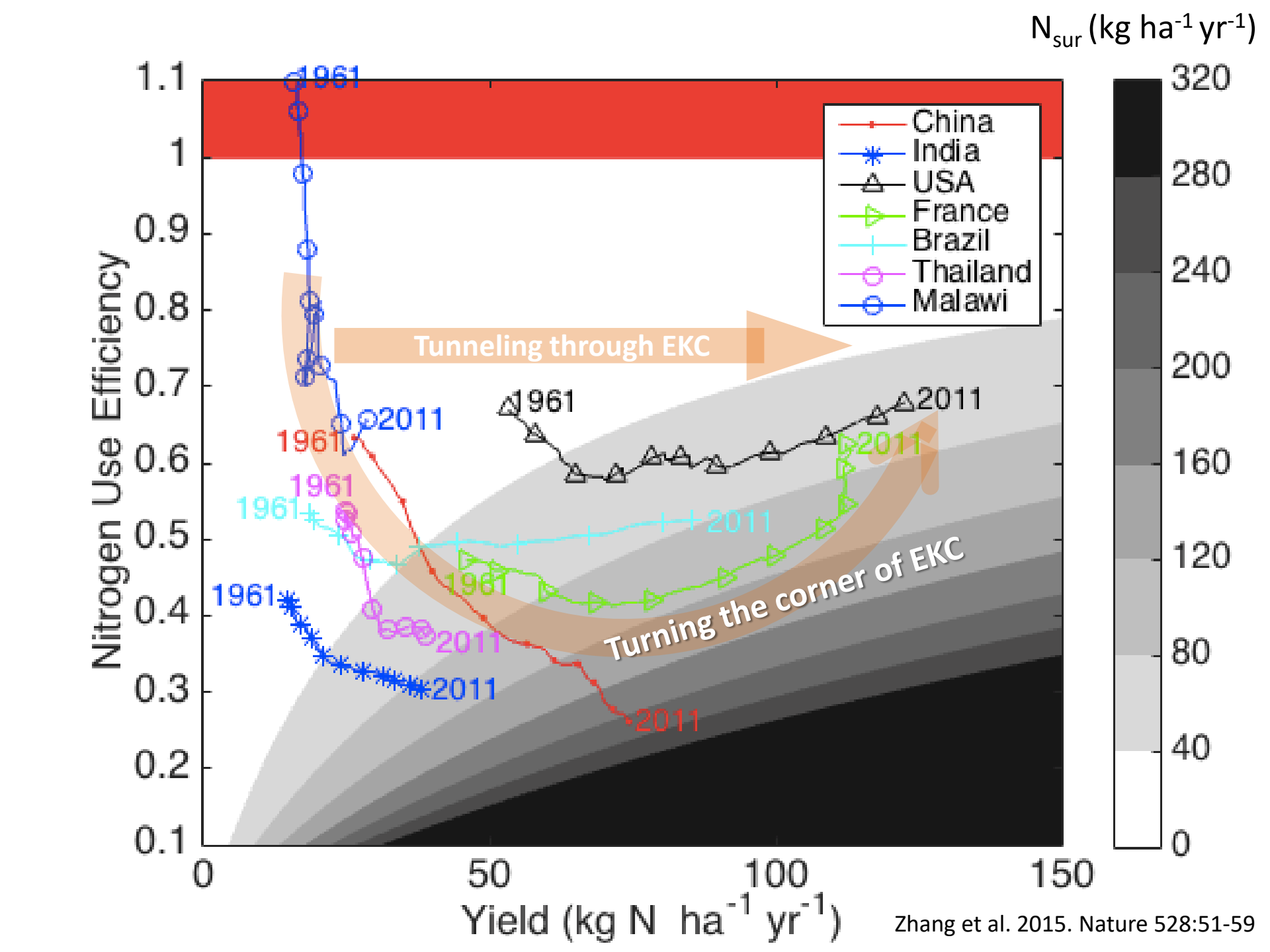
Zhang et al. 2015. Nature 528:51-59



$$NUE = N_{yield}/Inputs$$

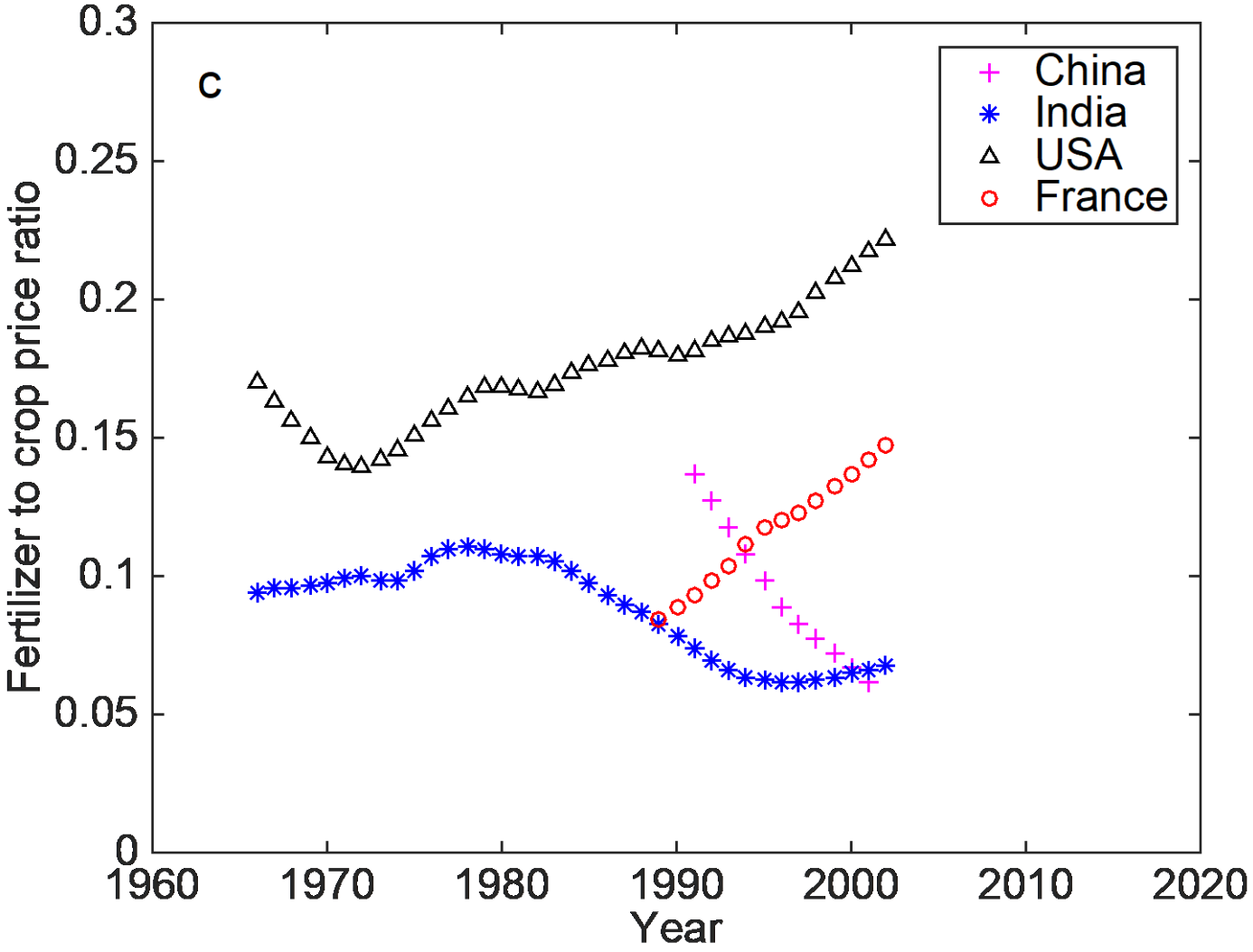
$$N_{sur} = Inputs - N_{yield}$$

$$N_{sur} = N_{yield}\left(\frac{1}{NUE} - 1\right)$$



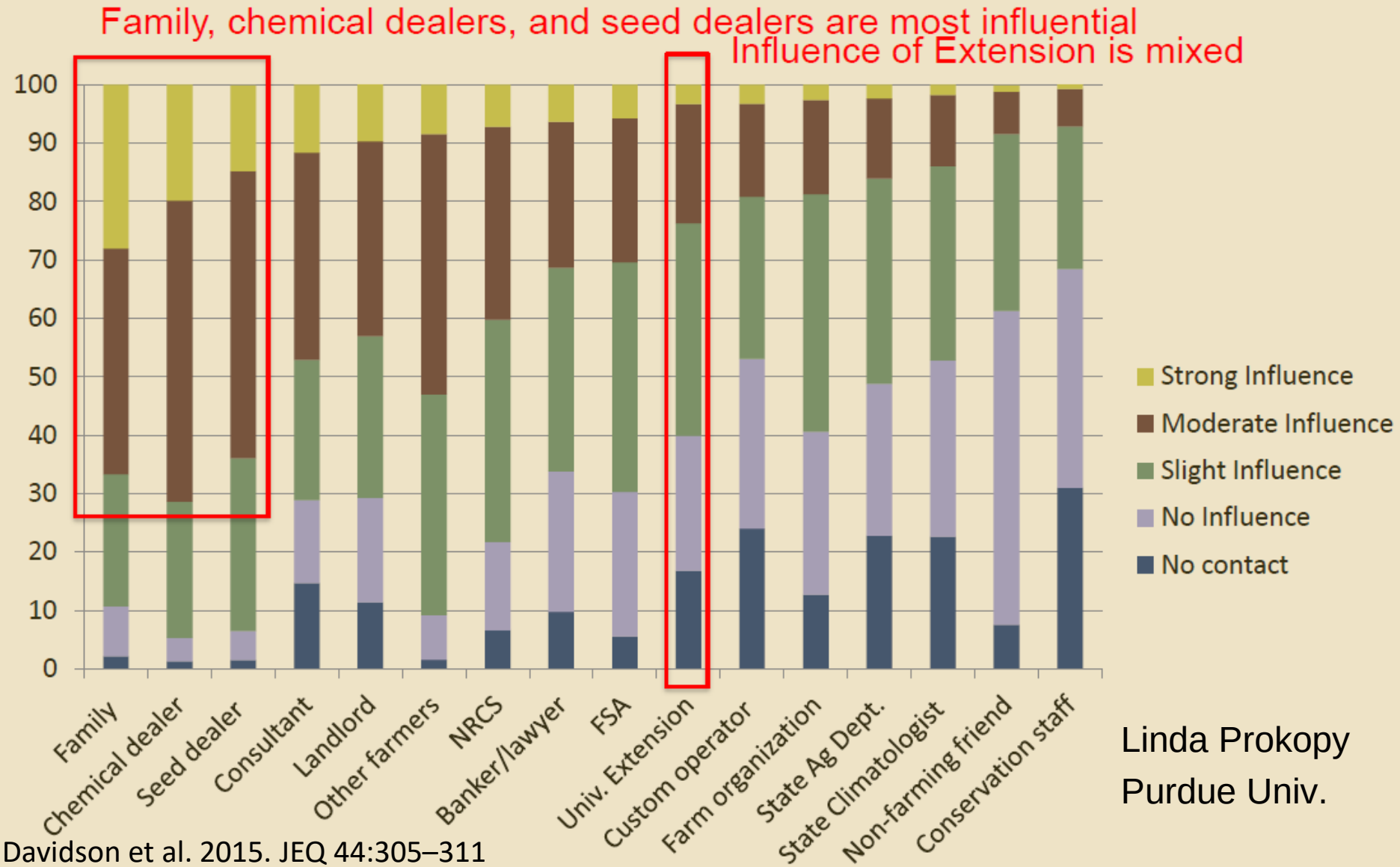
Zhang et al. 2015. Nature 528:51-59

Strong fertilizer subsidies have kept the fertilizer/crop price ratios low in China and India, which discourages NUE



Zhang et al. 2015. Nature 528:51-59

Please indicate how influential the following groups and individuals are when you make decisions about agricultural practices and strategies. (16 options)

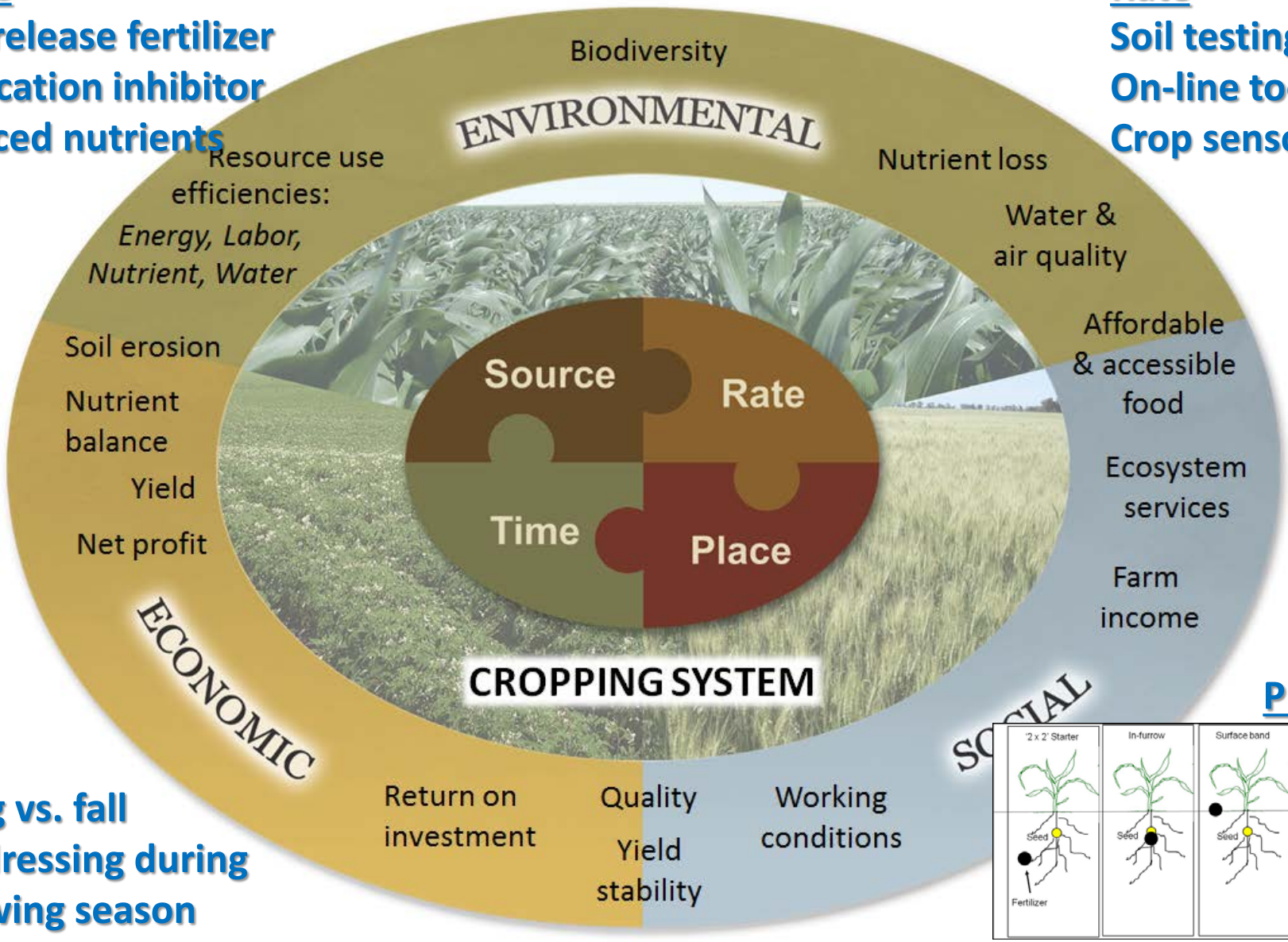


Linda Prokopy
Purdue Univ.

Davidson et al. 2015. JEQ 44:305–311

Source
Slow-release fertilizer
Nitrification inhibitor
Balanced nutrients

Rate
Soil testing
On-line tools
Crop sensors



Time
Spring vs. fall
Side dressing during growing season

Place

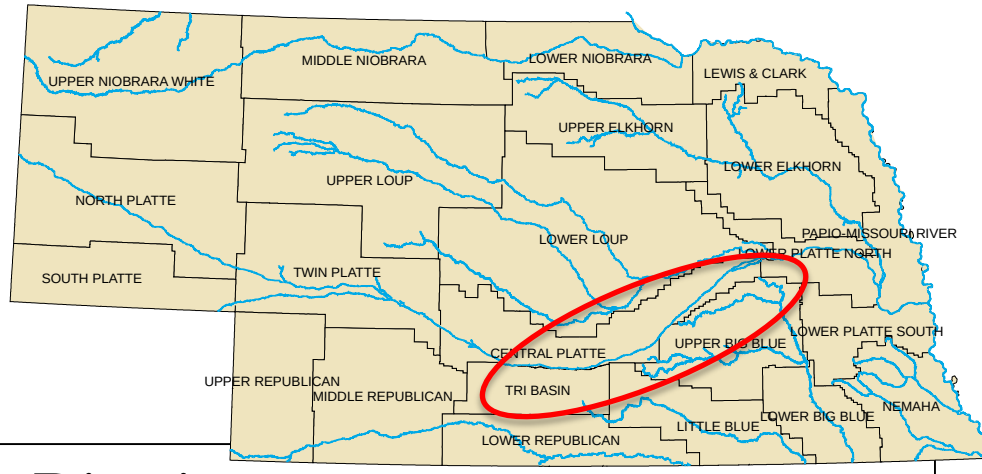
Applying the *Right Source* at the *Right Rate* at the *Right Time* and in the *Right Place, where Right* is defined by practice impact on system performance

Paul Fixen
IPNI
INTERNATIONAL PLANT NUTRITION INSTITUTE

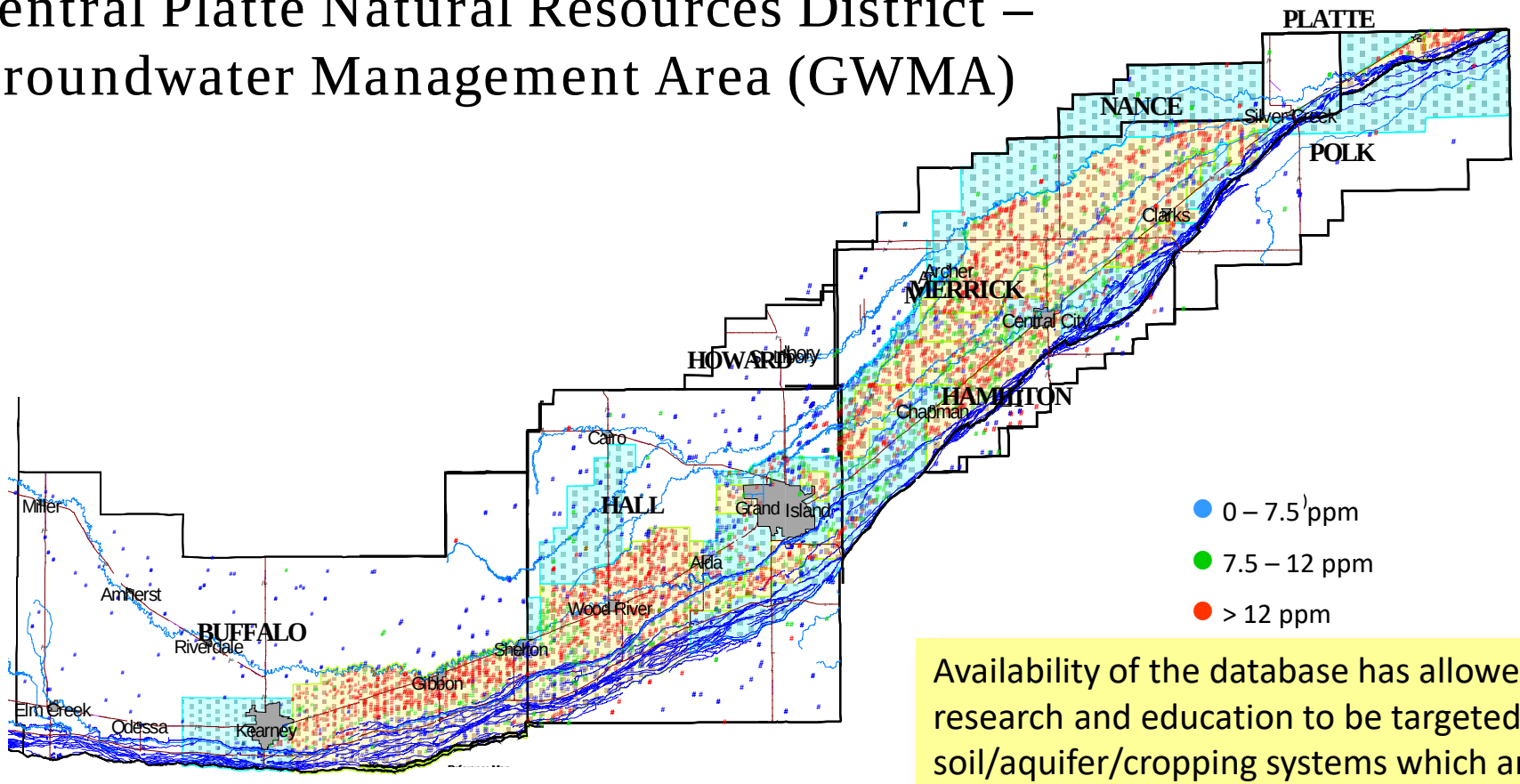
Project SENSE Means	Grower	SENSE
Fertilizer N (lb/acre)	192	150
Yield (bu/acre)	226	221
PFP_N (lb grain/lb N)	68	87

A research/educational project of the Nebraska Corn Board, the Central Platte, Little Blue, Lower Loup, Lower Platte North and Upper Big Blue Natural Resources Districts, USDA-NIFA, and the University of Nebraska-Lincoln On-Farm Research Network

Richard Ferguson; Univ. Nebraska



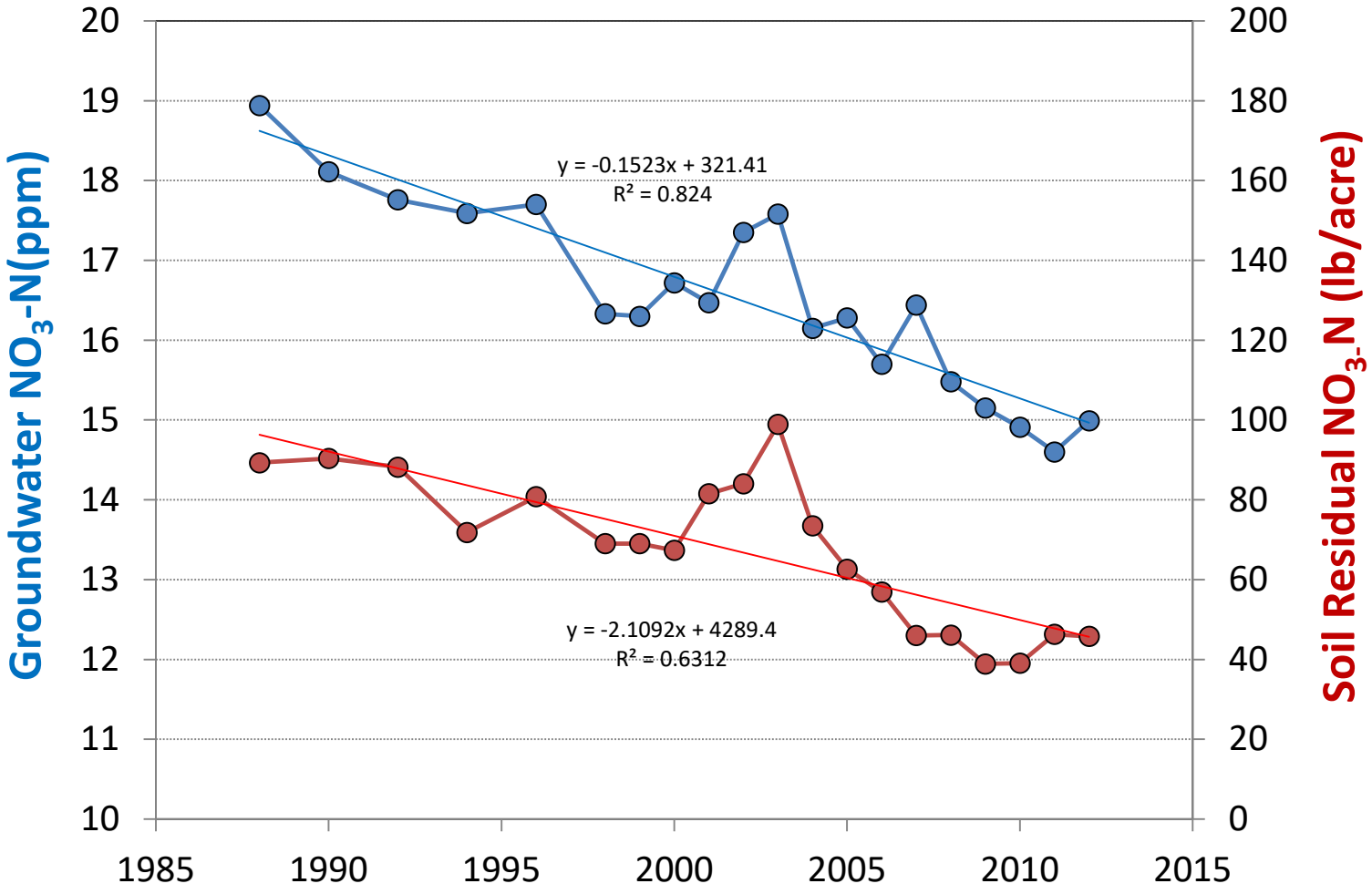
Central Platte Natural Resources District – Groundwater Management Area (GWMA)



Availability of the database has allowed both research and education to be targeted to soil/aquifer/cropping systems which are more challenging to manage.

Richard Ferguson: Univ. Nebraska

Trends in the Central Platte Valley



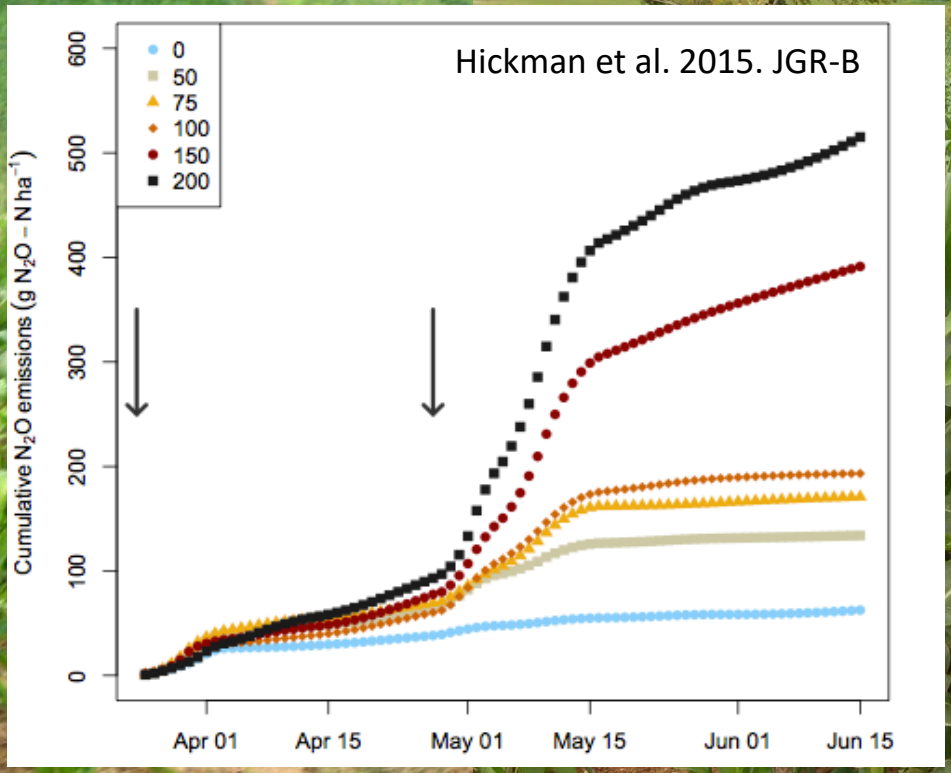
Average of values from producer reports in GWMA, representing ~ 300,000 acres

Richard Ferguson; Univ. Nebraska

Initial Goal of African Green Revolution
Moving from 1 to 3 tons per hectare

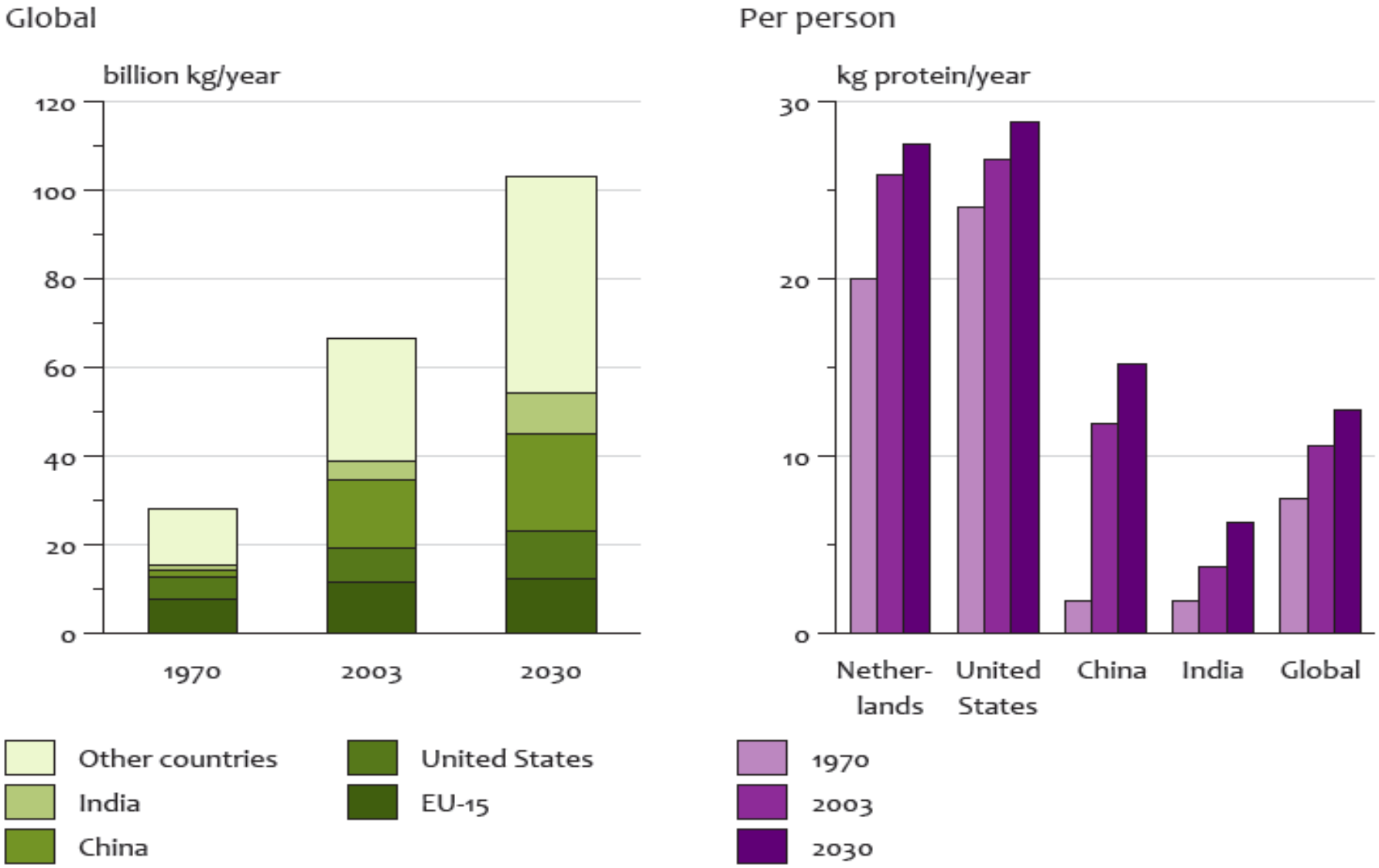
0 N added = 1 ton/ha maize
60-70% of water lost through evaporation

50 kg N ha^{-1} = 3 tons/ha maize
30 -40% of water lost through evaporation



Cheryl Palm & Pedro Sanchez, Columbia University

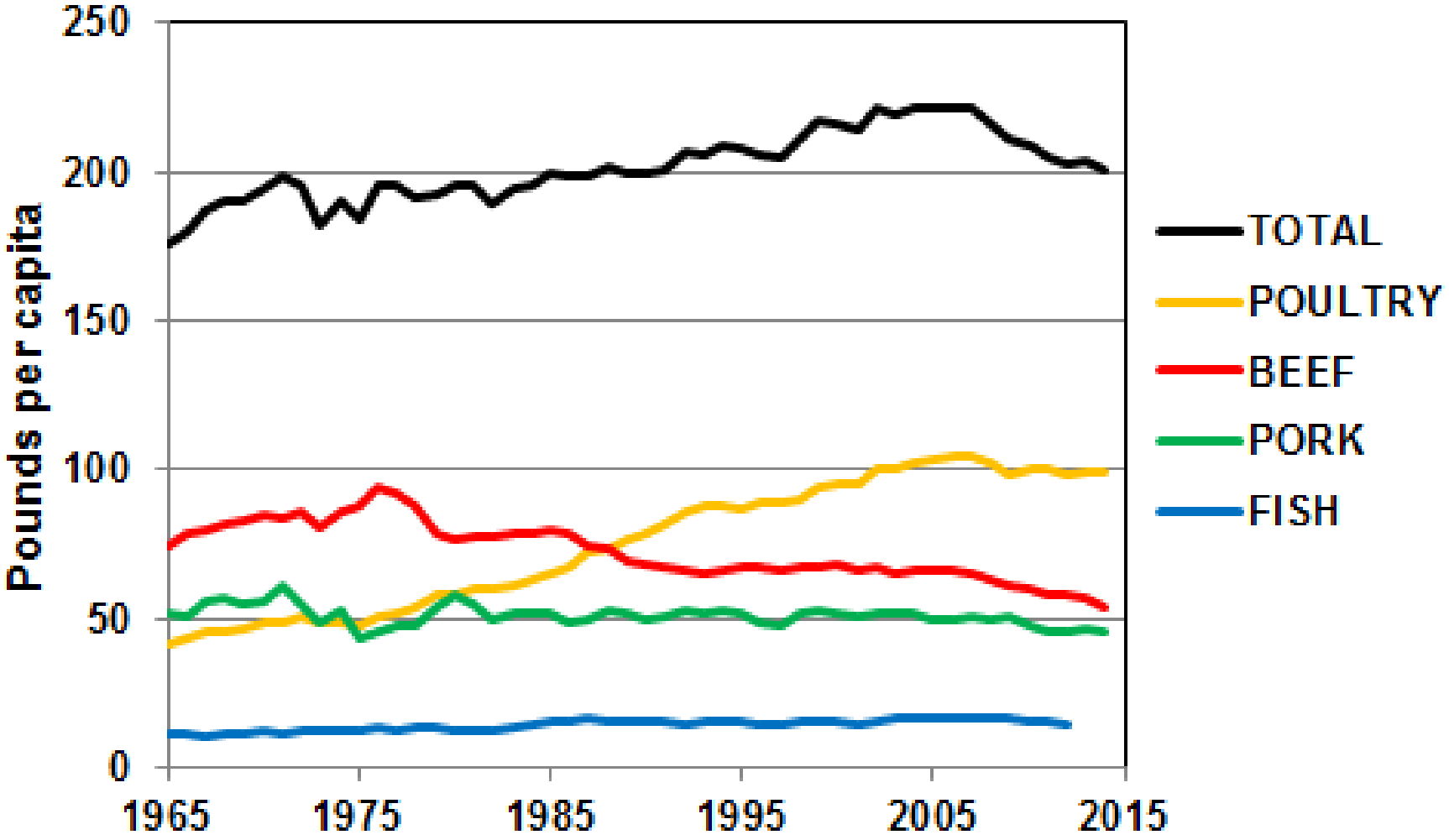
Increasing consumption of animal protein



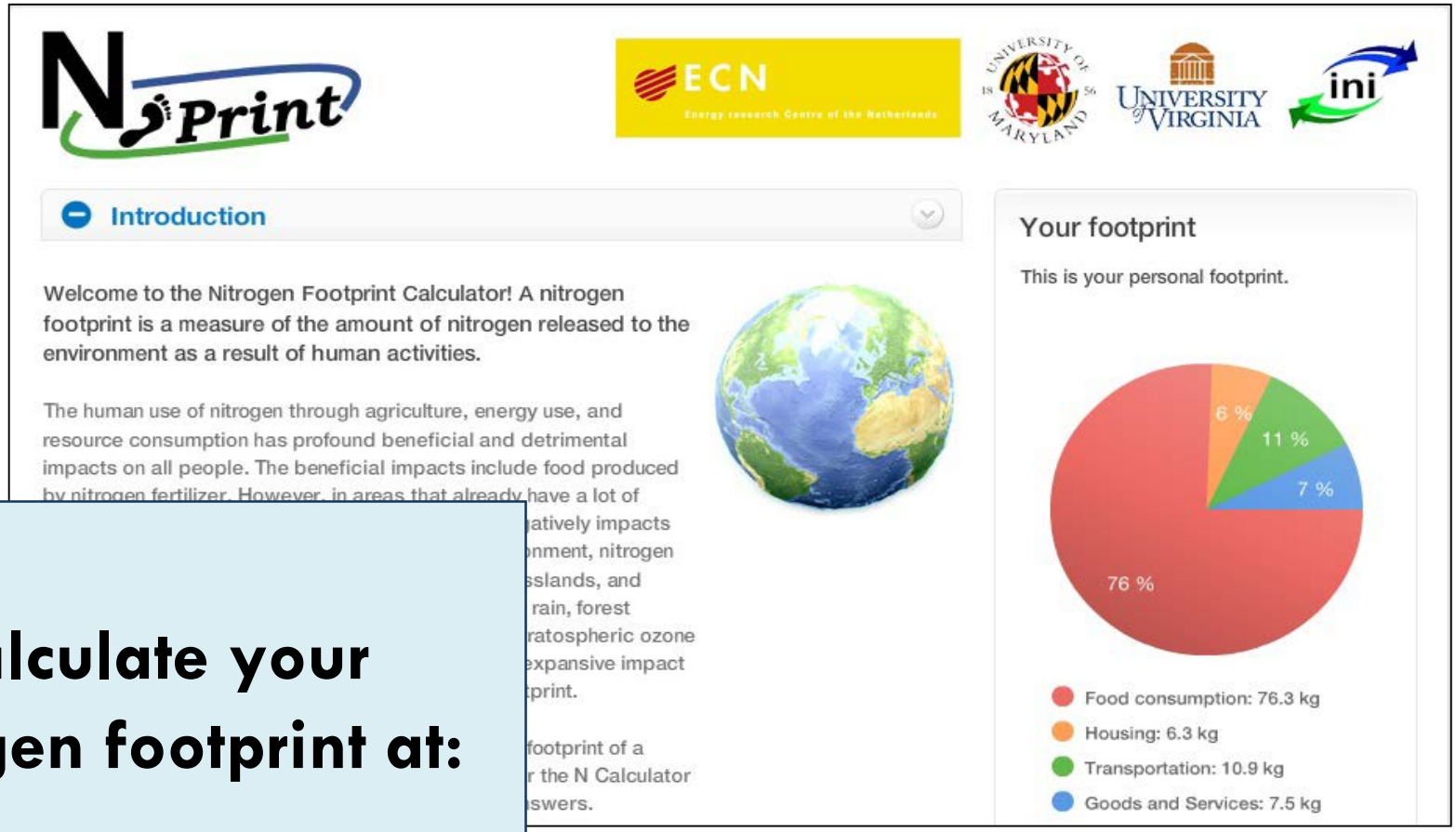
Westhoek et al. (2011) “The Protein Puzzle”
Reay et al. (2011) European Nitrogen Assessment

Per capita meat consumption has started to decline in the USA, especially beef consumption.

http://www.nationalchickencouncil.org/



2 Personal N footprints

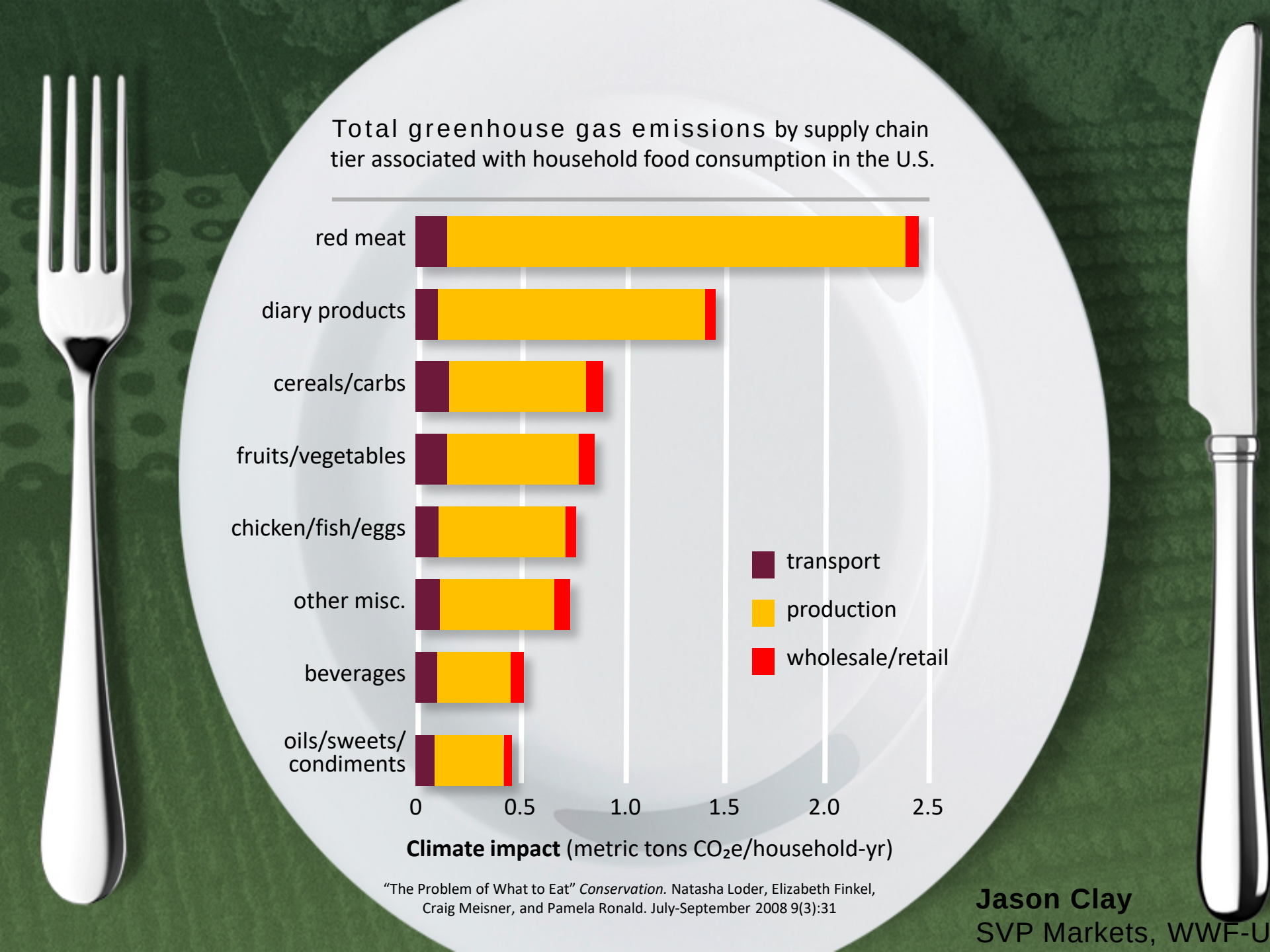


Calculate your nitrogen footprint at:

www.N-Print.org

Allison Leach

University of New Hampshire



"The Problem of What to Eat" *Conservation.* Natasha Loder, Elizabeth Finkel, Craig Meisner, and Pamela Ronald. July-September 2008 9(3):31

Jason Clay
SVP Markets, WWF-U

Take-home messages

- **Sustainable intensification can improve NUE, increase crop yields, and reduce N pollution, and**
- **Technological advances will be helpful and a lot can be done with existing technology, but**
- **Social and economic impediments remain, therefore**
- **MoFoLoPo will require integration among agronomy, social sciences, and other disciplines and cooperation across sectors and stakeholder groups, and**
- **Personal dietary choices matter**

Thank you for your attention
Bon appétit!