Mesoscale Data Fusion to Map and Model the U.S. Food-Energy-Water system

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Other partners . . .

- Columbia Water Center, Earth Institute | Columbia University
- NREL, National Renewable Energy Laboratory
- Oak Ridge National Laboratory
- Sandia National Laboratories
- USGS, science for a changing world
- Sustainable Waters, Solutions in a Time of Scarcity
- The Nature Conservancy

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PERSPECTIVE

The U.S. food–energy–water system: A blueprint to fill the mesoscale gap for science and decision-making

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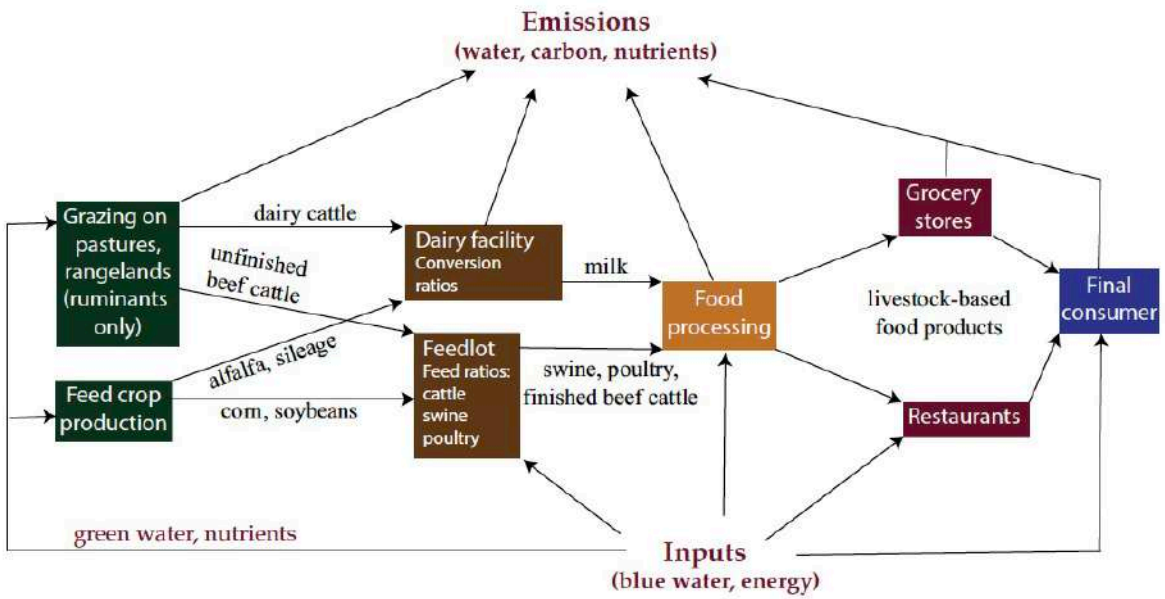
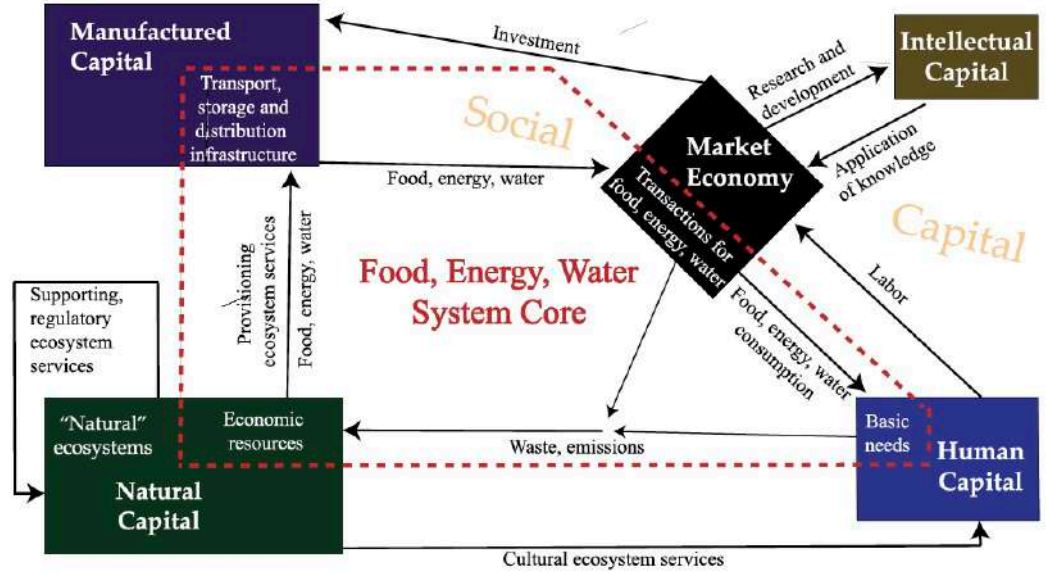
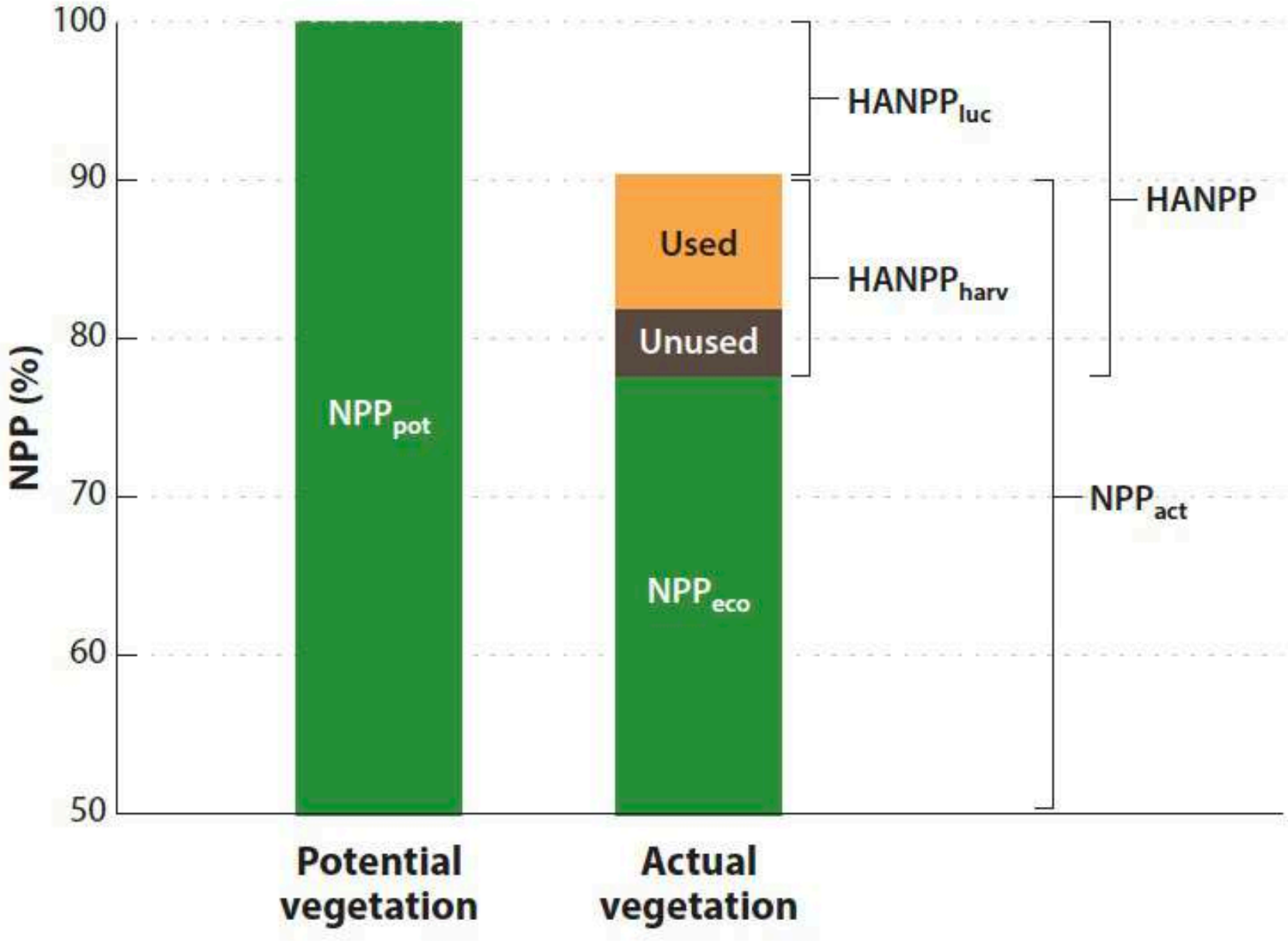




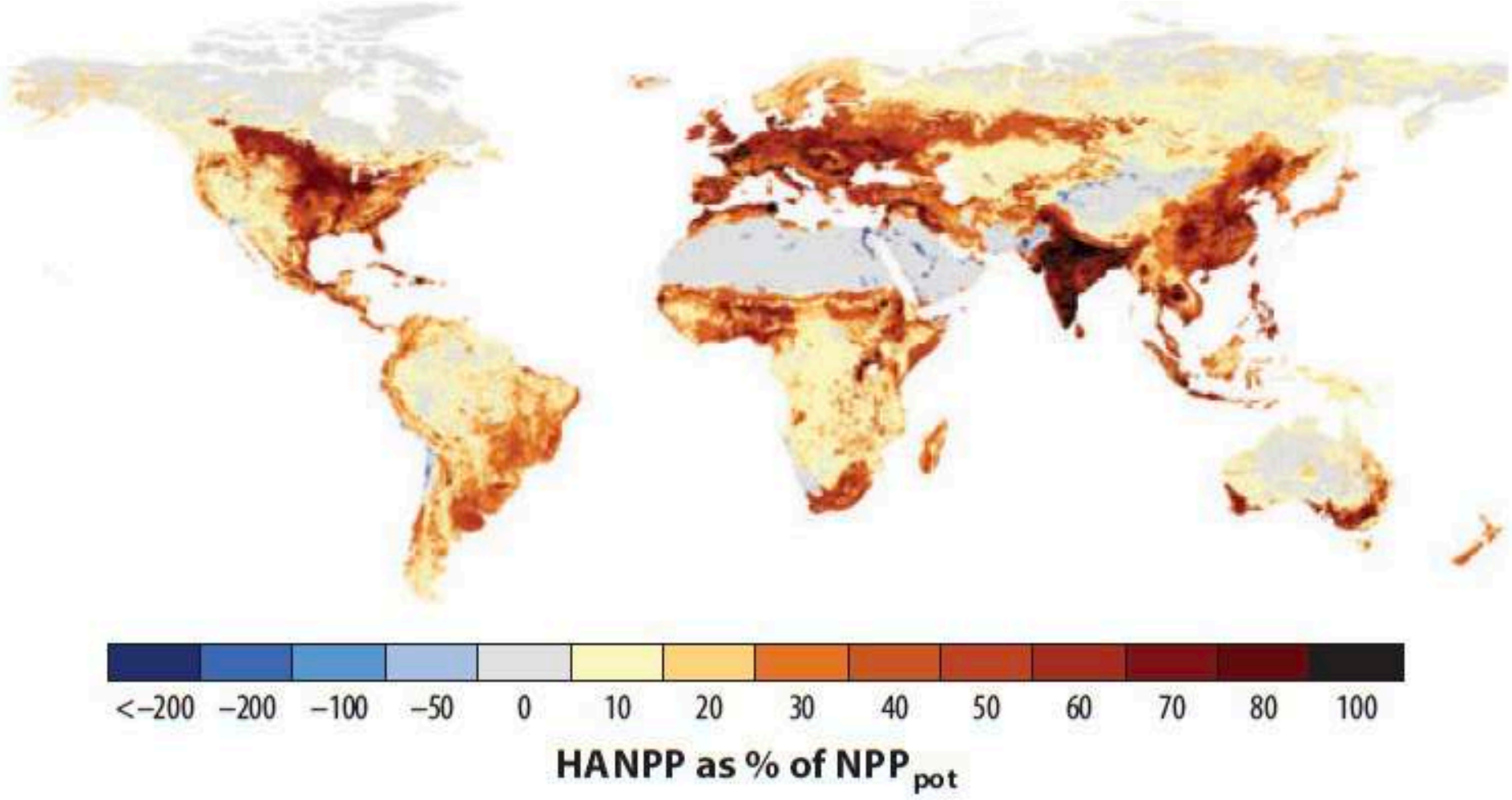


What is **human appropriation of net primary production** (HANPP)?

From Vitousek (1980s) to Institute of Social Ecology in Vienna (21st C)
(source Haberl et al. 2014)

GPP - plant respiration
= NPP
= rate of biomass accumulation
0-1500g $Cm^{-2}yr^{-1}$

Global Distribution of HANPP as a % of NPP. How intensely does land use degrade or harvest the ecosystem? Source Haberl et al. 2014. *Annual Review of Environmental Resources* 39:363-391



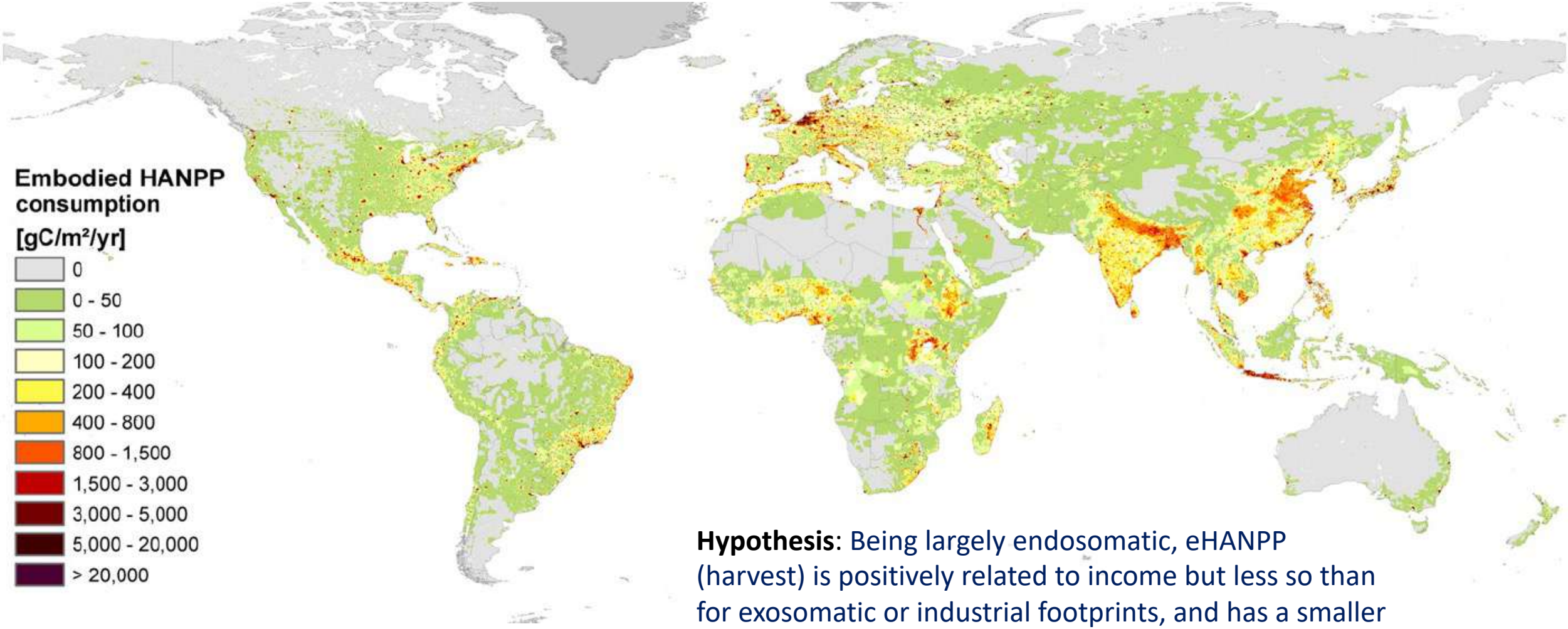
Global GPP = 110-120 $PgCyr^{-1}$

NPP/GPP ratio = ~0.5

Global NPP = ~55-60 $PgCyr^{-1}$

HANPP = ~20-30% NPP = 12-18 $PgCyr^{-1}$

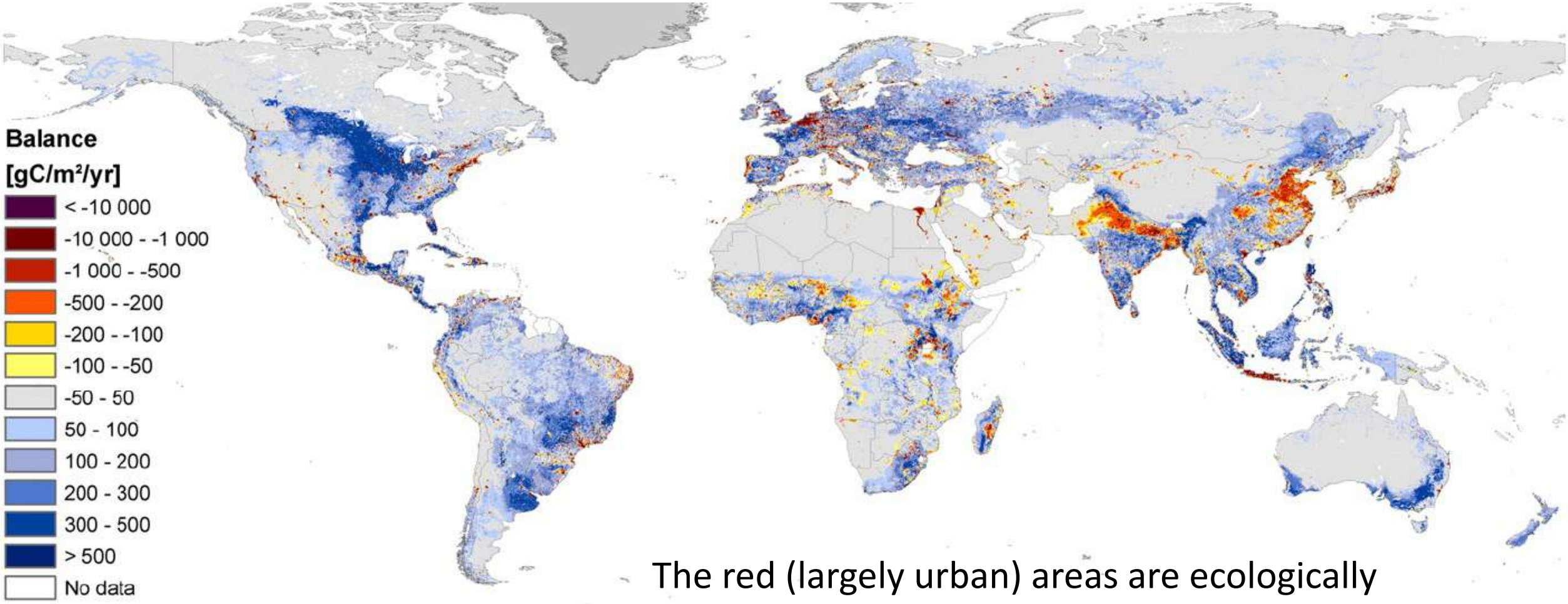
What is eHANPP?: Embodied human appropriation of net primary productivity (consumption of HANPP)



Source: Erb et al 2009. *Ecological Economics*.

Hypothesis: Being largely endosomatic, eHANPP (harvest) is positively related to income but less so than for exosomatic or industrial footprints, and has a smaller coefficient of variation than industrial footprints over time and space.

The Balance between HANPP (production) and eHANPP (consumption)



The red (largely urban) areas are ecologically dependent on the blue (largely rural) areas.

Source: Erb et al 2009. *Ecological Economics*.

Calculating HANPP from yield for crops or timber

Net Primary Productivity =
(Yield * Area Harvested * Dry Fraction * Carbon content)/ (Harvest Index * % Shoot)

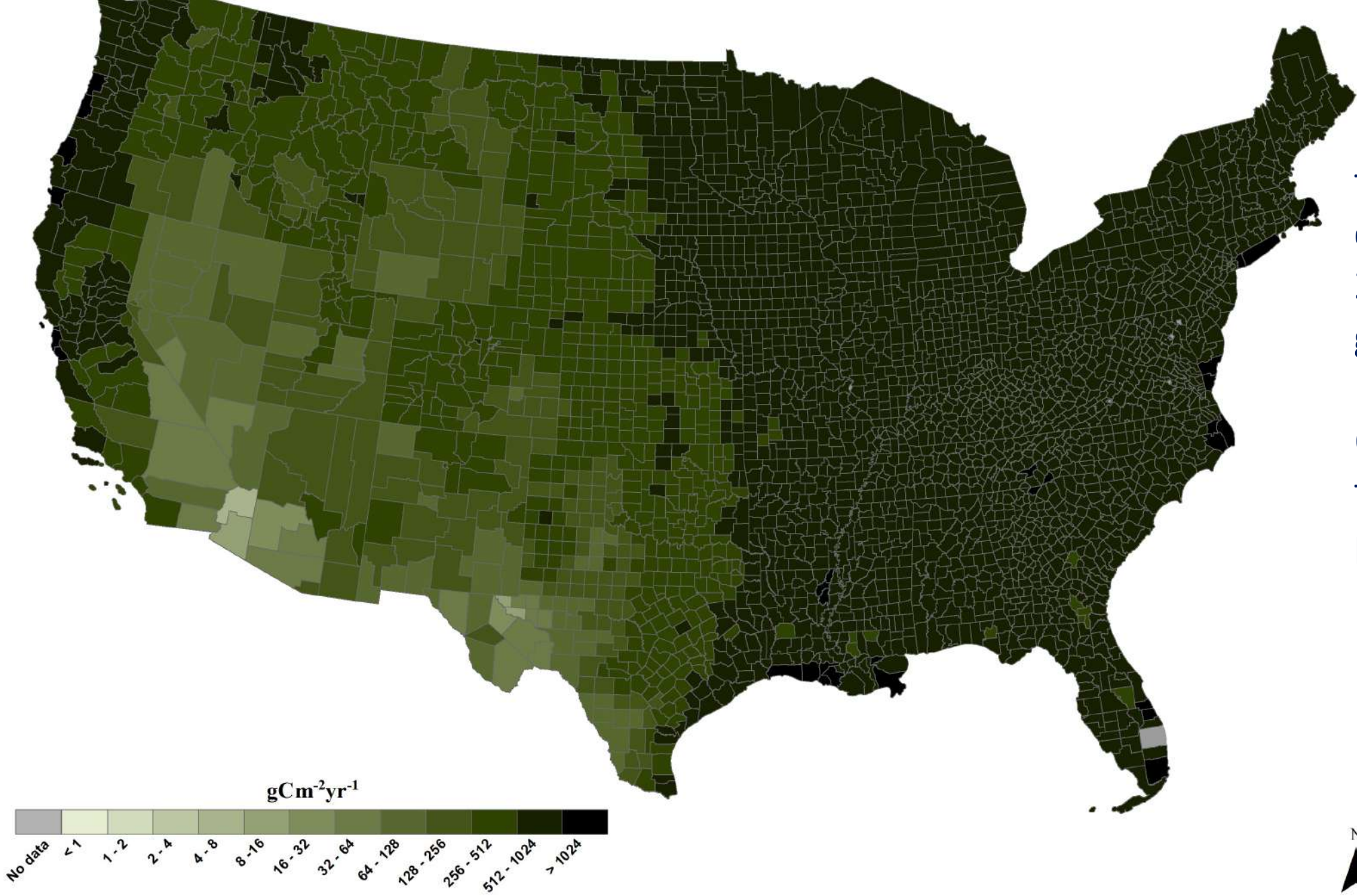
Net Primary Productivity (*aboveground*) =
(Yield * Area Harvested * Dry Fraction * Carbon content)/ (Harvest Index)

Net Primary Productivity (*used*) =
(Yield * Area Harvested * Dry Fraction * Carbon content)/ (% Shoot)

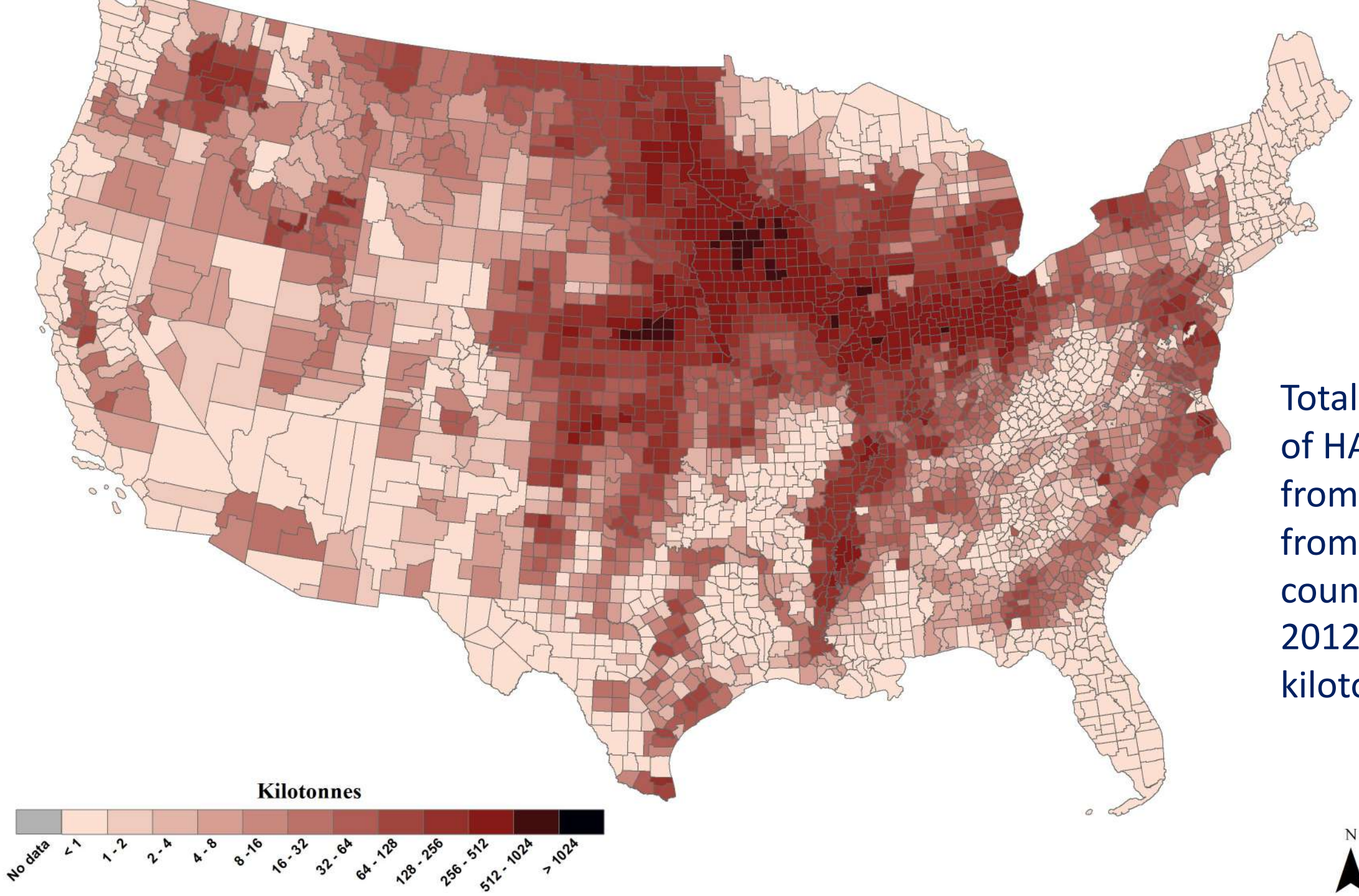
Stoichiometry for converting crop yield to HANPP for each crop

Crop	Dry fraction	Carbon content	% Shoot	Harvest index
corn grain	0.845	0.45	0.85	1940: 0.35; linear interpolate to 2000: 0.53; >2000: 0.53
corn silage	0.35	0.45	0.85	1.0
winter, spring, durum wheat	0.865	0.45	0.83	1940: 0.28; linear interpolate to 2000: 0.45; >2000: 0.45
soybeans	0.87	0.45	0.87	1940: 0.30; linear interpolate to 2000: 0.46; >2000: 0.46
alfalfa-hay	0.82	0.45	0.46	1.0
upland and pima cotton	0.935	0.45	0.86	1940: 0.35; linear interpolate to 1978: 0.47; >1978: 0.47
sorghum	0.88	0.45	0.86	1940: 0.34; linear interpolate to 2000: 0.47; >2000: 0.47
Other crops	0.86	0.45	0.85	1940: 0.34; linear interpolate to 2000: 0.48; >2000: 0.48

Sources: Alberta Agriculture and Forestry 2019, Bolinger, et al. 2002, Evans 1993, Hellevang 2020, Johnson et al. 2006, Kumudini et al. 2001, McMichael and Quisenberry 1991, National Cotton Council 1990, Ontario Ministry of Agriculture 2018, Pettigrew 2008, Prince, et al. 2001, Schlesinger and Bernhardt 2013, Smith 2007, Tollenaar 1989, Wells 2016.

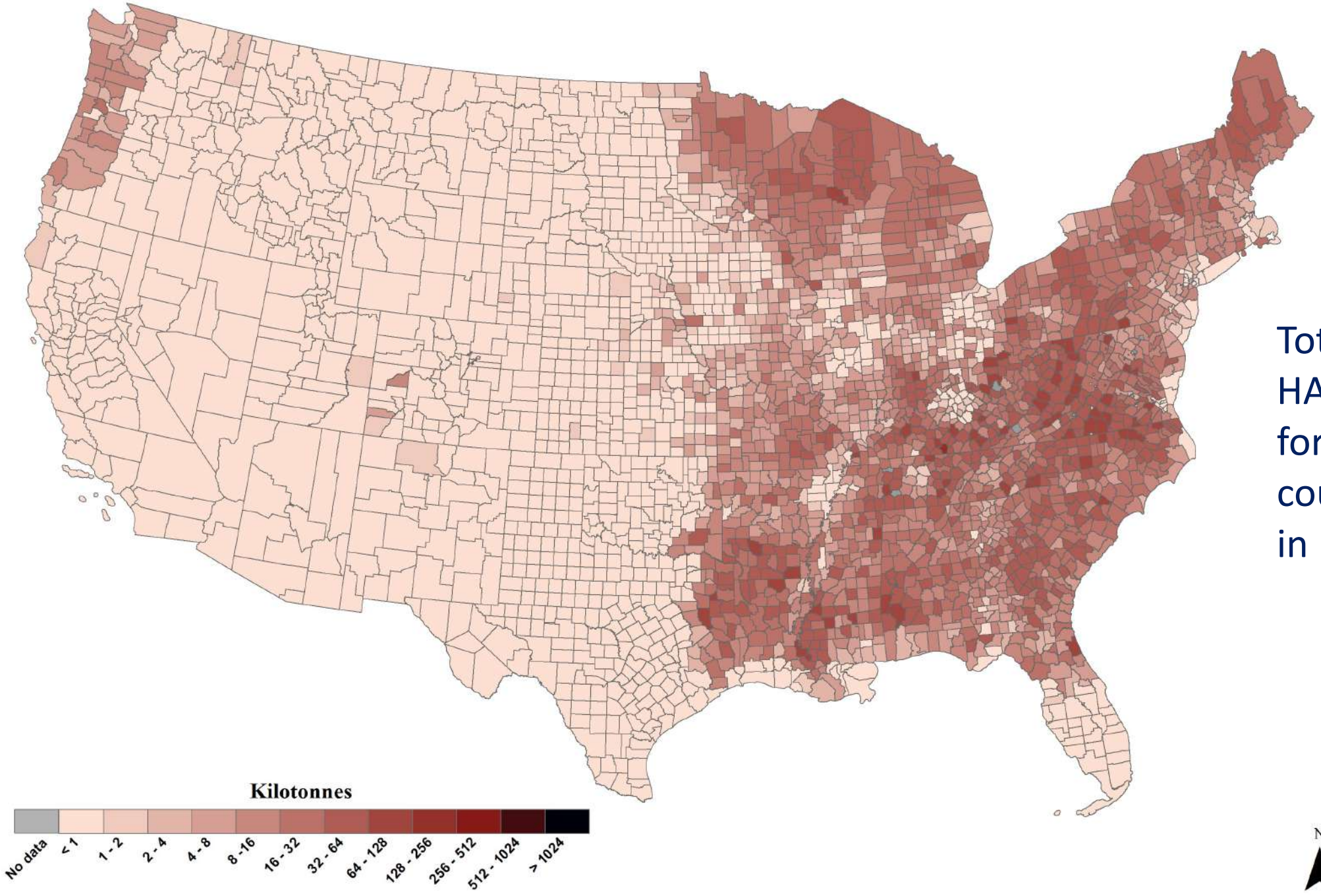


NPP density for U.S. counties in 2012 in $gCm^{-2}yr^{-1}$ from Landsat Data (aggregating from 30m pixels)

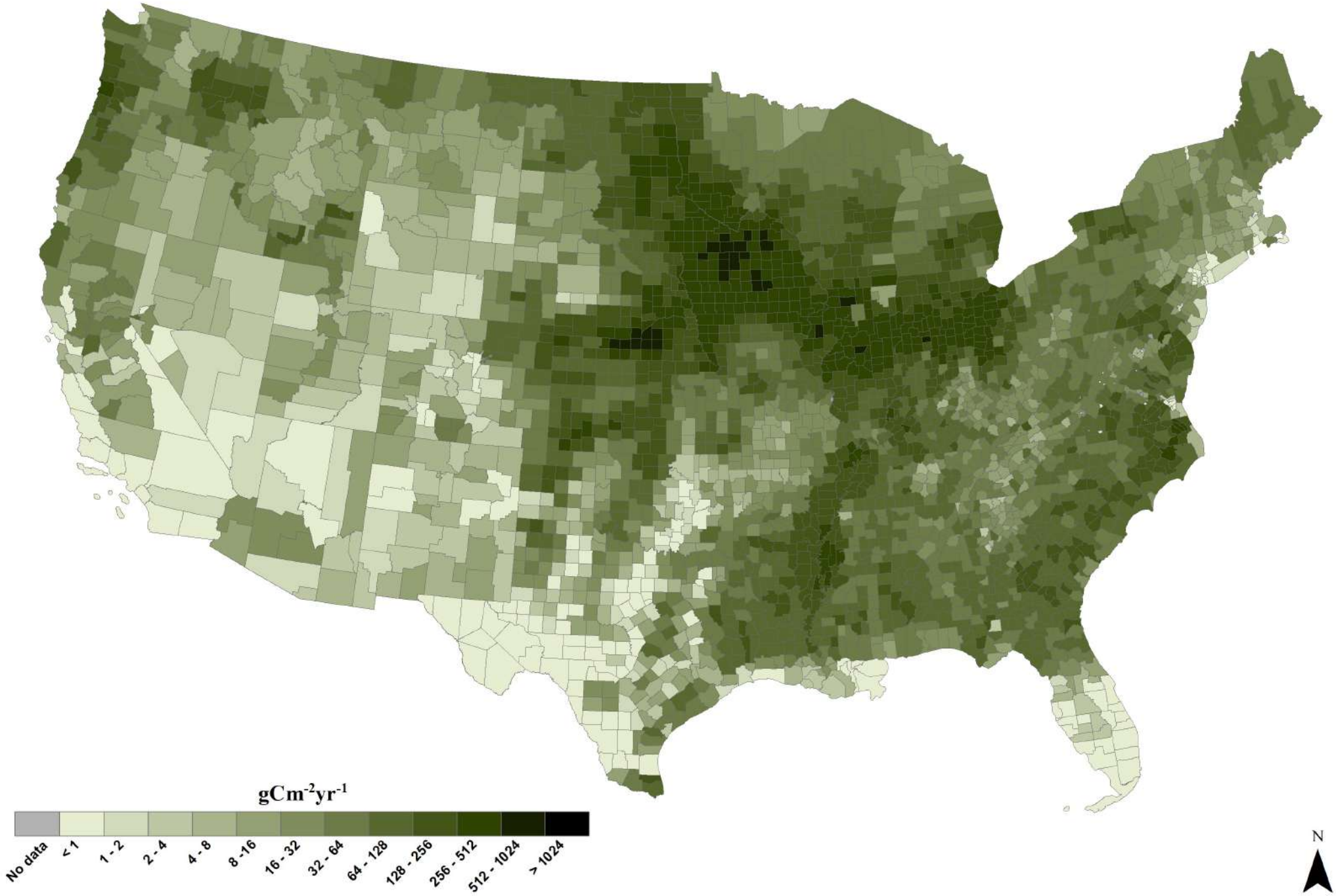


Total harvest of HANPP from crops from US counties in 2012 in kilotonnes

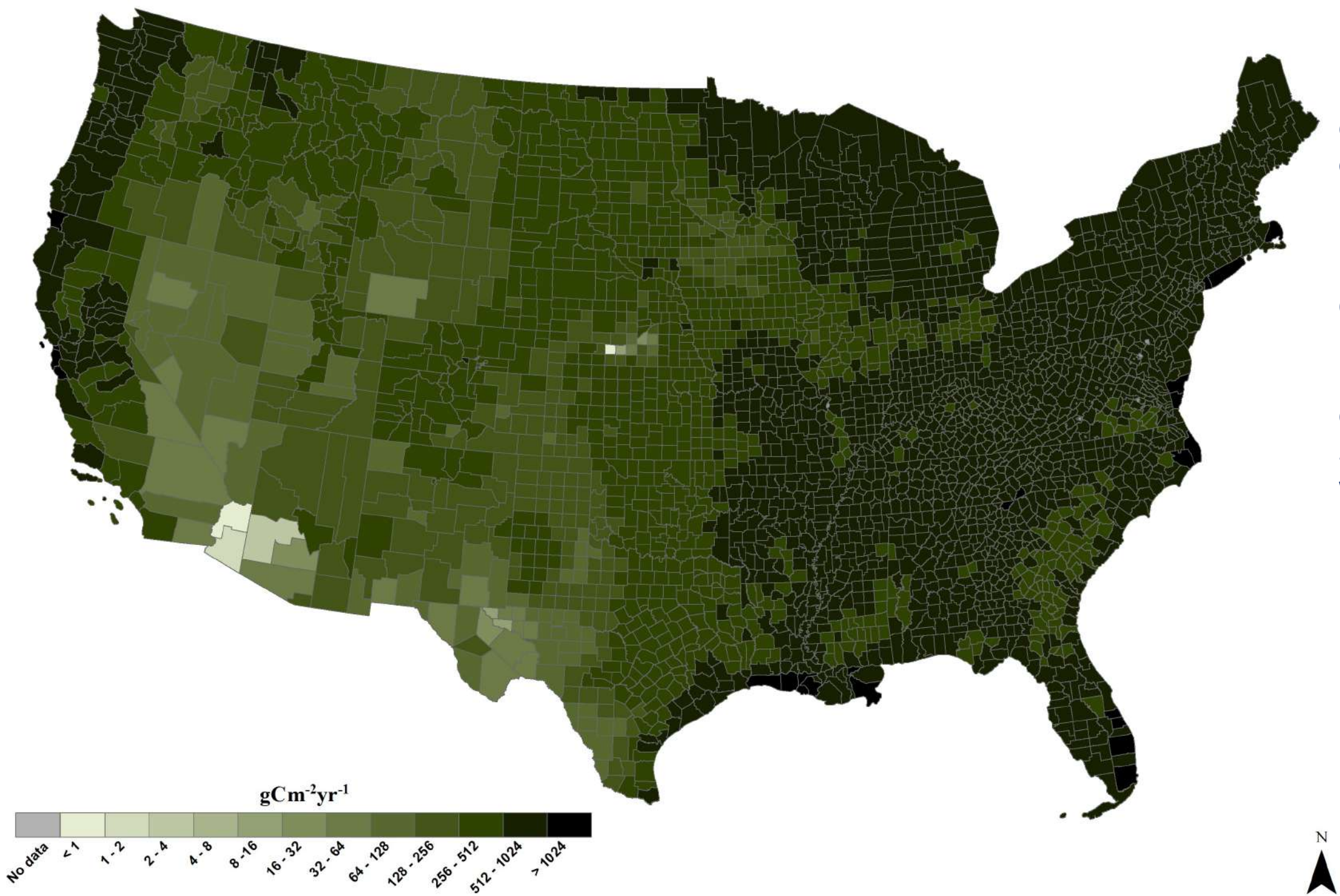
HANPP Forestry



Total harvest of HANPP from forestry from US counties in 2012 in kilotonnes



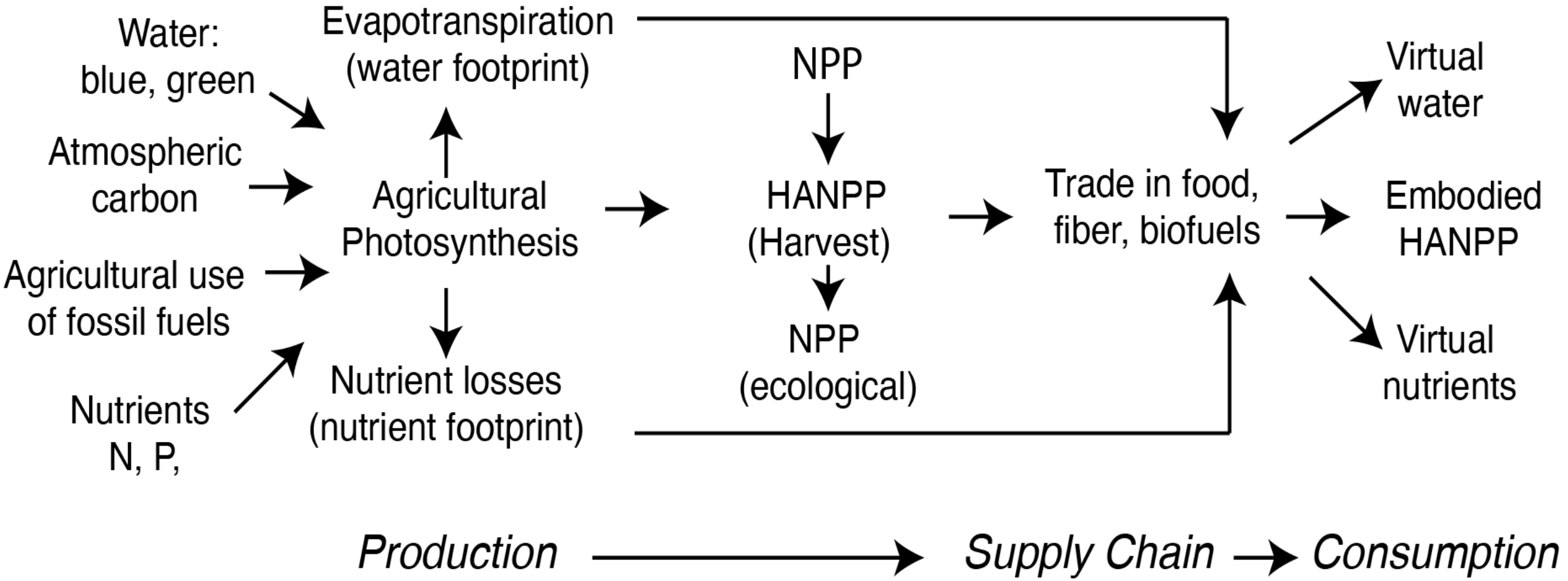
HANPP (harvest) density for U.S. counties in 2012 in $gCm^{-2}yr^{-1}$



NPP (ecological) density for U.S. counties in 2012 in $gCm^{-2}yr^{-1}$

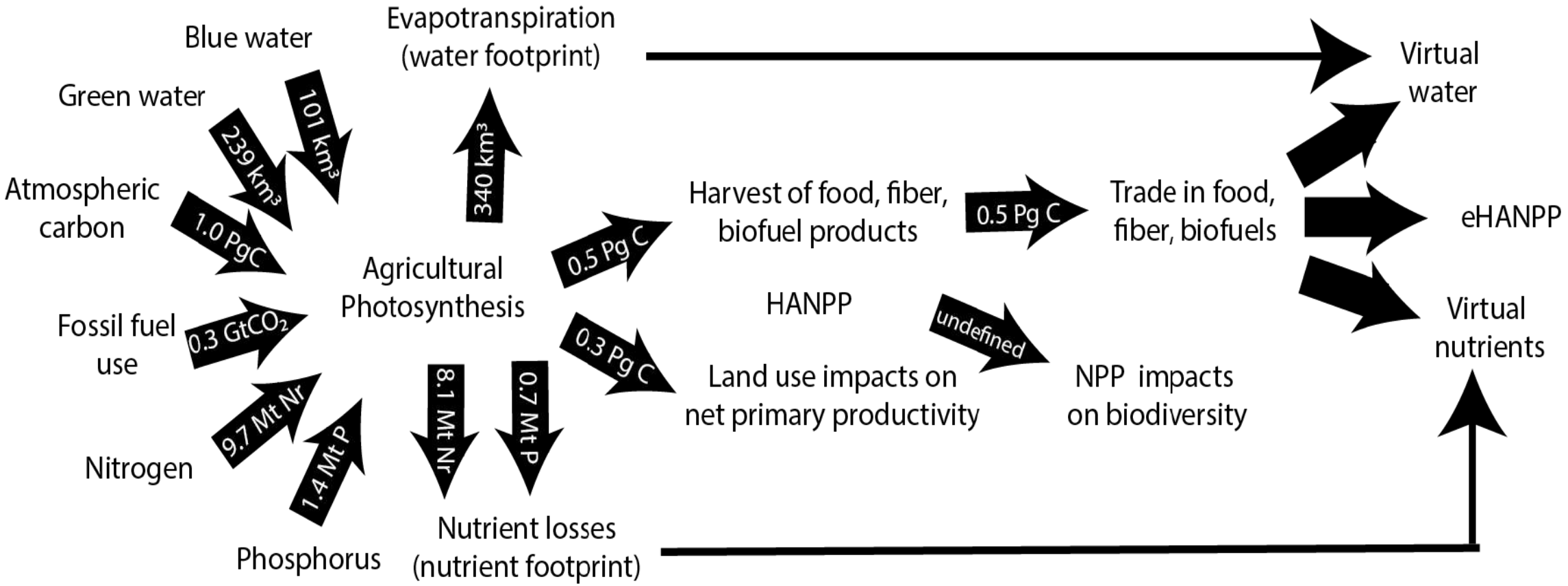
Landsat and Cropland Data Layer can be used to disaggregated to 30m pixels where forest harvest is not important.

Functional relationships between HANPP, water, nutrient and carbon footprints along the supply chain



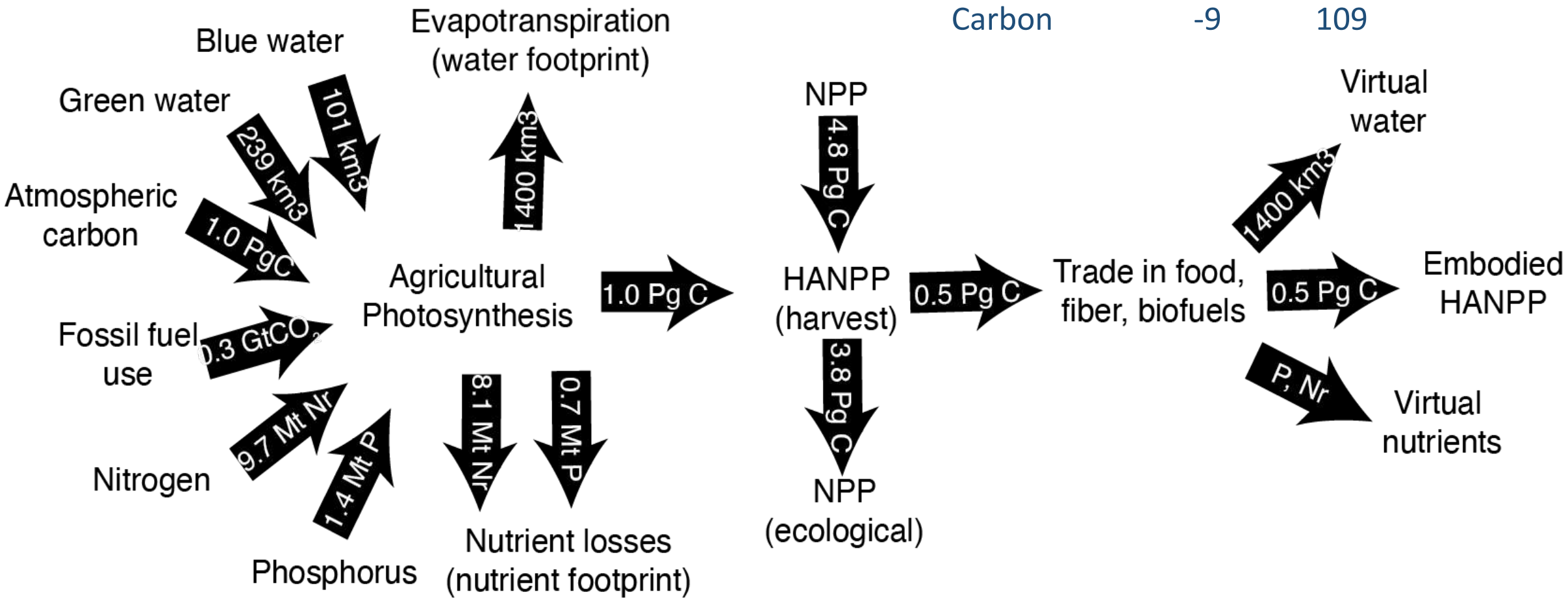
Approximate Quantitative Relationships around HANPP Global early 21st Century

Footprint.	Ecological	Industrial
HANPP	100	0
Green Water	100	0
Blue Water	92	8
Nitrogen	65	35
Phosphorus	90	10
Carbon	25	75



Approximate Quantitative Relationships around HANPP U.S. early 21st Century

Footprint.	Ecological	Industrial
HANPP	100	0
Green Water	100	0
Blue Water	77	23
Nitrogen	71	29
Phosphorus	90	10
Carbon	-9	109



What would this map look like for trade in various biomass products?
What are the teleconnections?