Feb 13 Primary Productivity: Comparison among Biomes

Central Surinam Reserve, Humid Tropical

Introduction

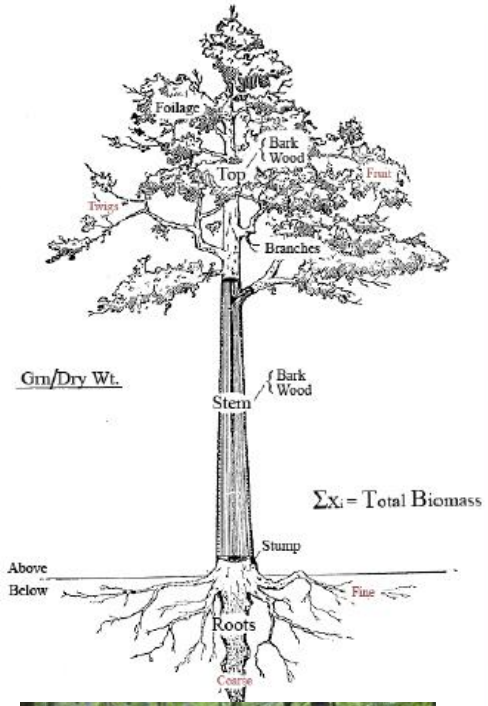
How does NPP vary from place to place?

Methods are challenging in forests

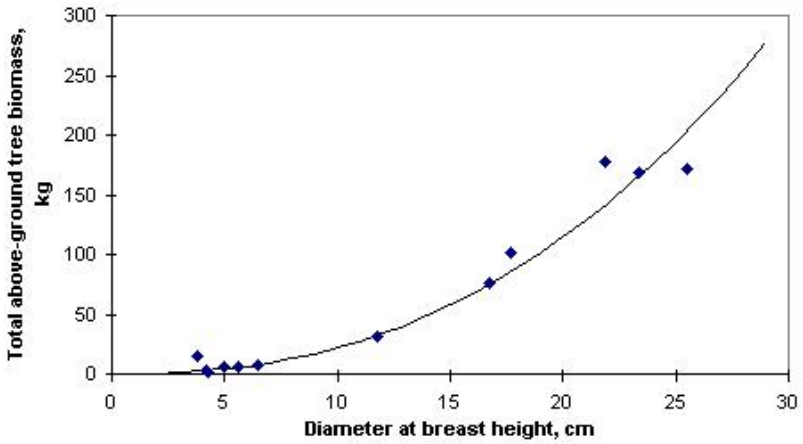
Typical field method – tree allometry and diameter increment.

Estimating NPP in a Stand via Allometry

1. Estimate biomass of whole trees within a species



2. Develop an equation predicting biomass from tree diameter



3. Do steps 1 and 2 for each tree and shrub species

4. Estimate tree and shrub density by diameter class within the stand

5. Use allometric equations to estimate stand biomass

6. Remeasure diameters of trees by species and size class or use tree ring increment.

7. Reestimate biomass from allometric equations.
NPP is Biomass at time 2 – biomass at time 1.

Introduction

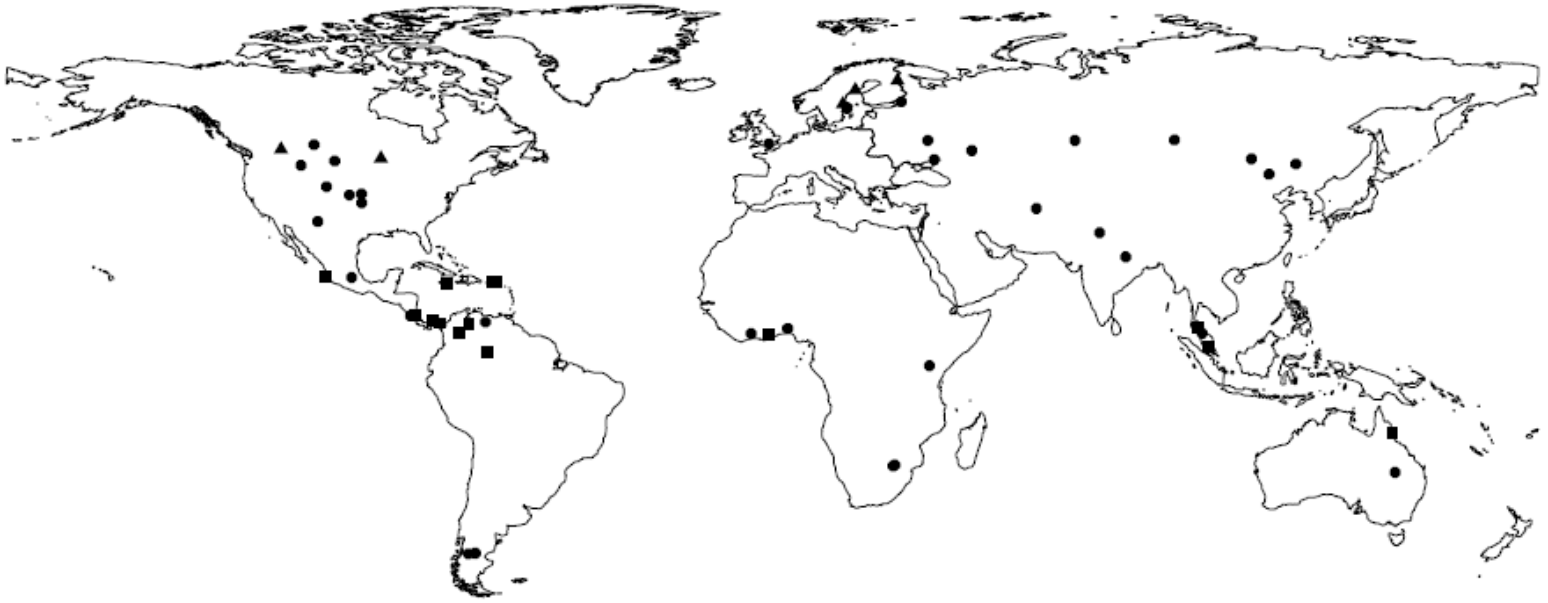
How does NPP vary from place to place?

- **Tree allometry and diameter increment in a stand.**

- **Compile many stand estimates and average within biomes**

Scurlock, J. M. O., and R. J. Olson. 2002. Terrestrial net primary productivity: a brief history and new worldwide database. Environmental Reviews (NRC-CNRC) 10:91–110.

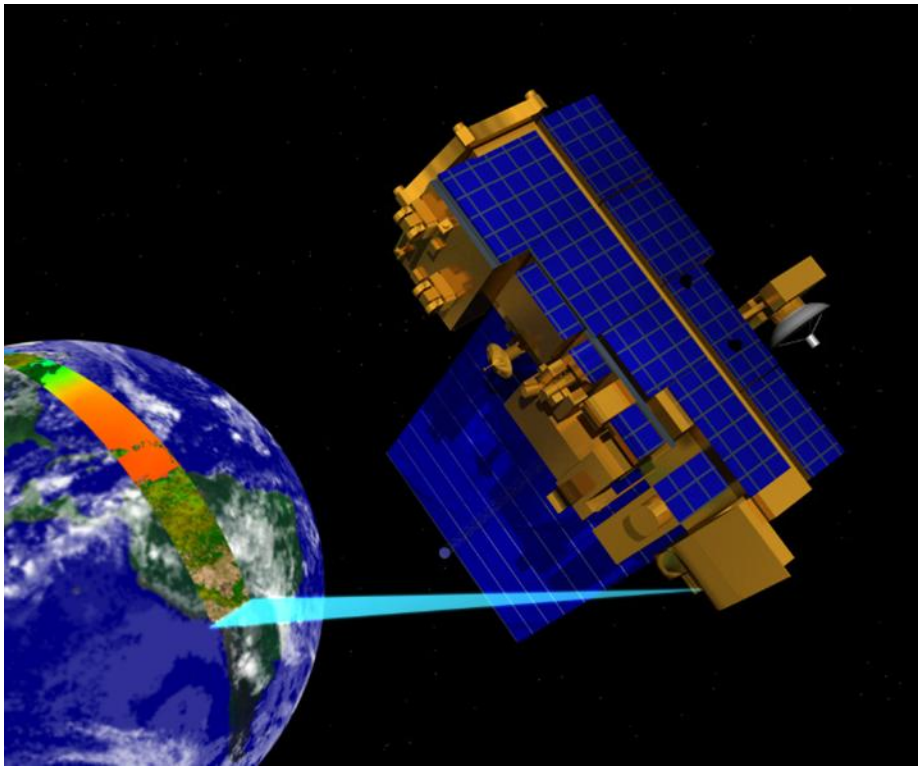
Fig. 1. Map showing the geographical distribution of intensive terrestrial NPP study sites in the ORNL DAAC database. ▲ = boreal forest sites, ● = grassland sites, ■ = tropical forest sites. Some points may be indistinct because of their close proximity.



Introduction

How does NPP vary from place to place?

- **Tree allometry and diameter increment in a stand.**
- **Compile many stand estimates and average within biomes**
- **Estimate from satellite data and simulation models**



Introduction

Topics

Running et al. 2004. Satellite derived estimates of NPP

Huston and Wolverton 2009. Controversial claim that Running et al. are wrong about the humid tropics.

Chapin et al. Chapter 6. Reconciling two viewpoints above?

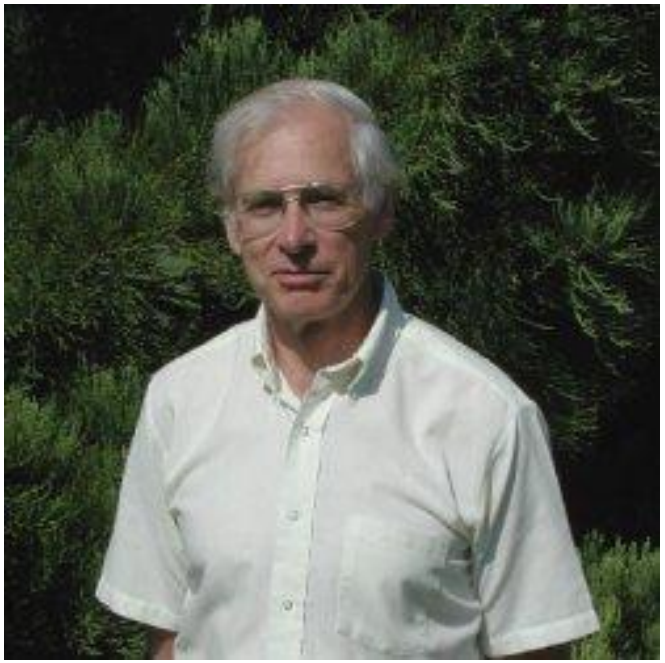
Implications of global patterns of NPP

NPP from Satellite Data

Concept

Can spectral reflectance from satellite data be used to estimate NPP globally?

Steve Running, Univ. Montana

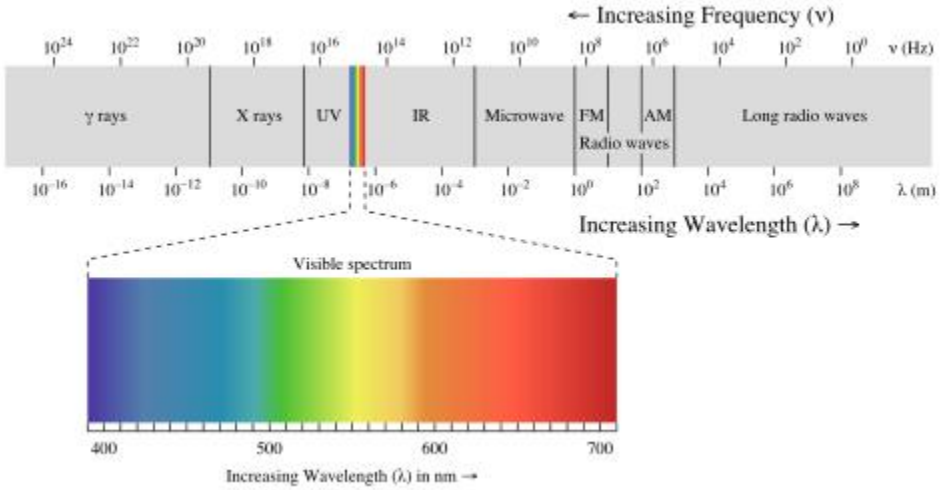


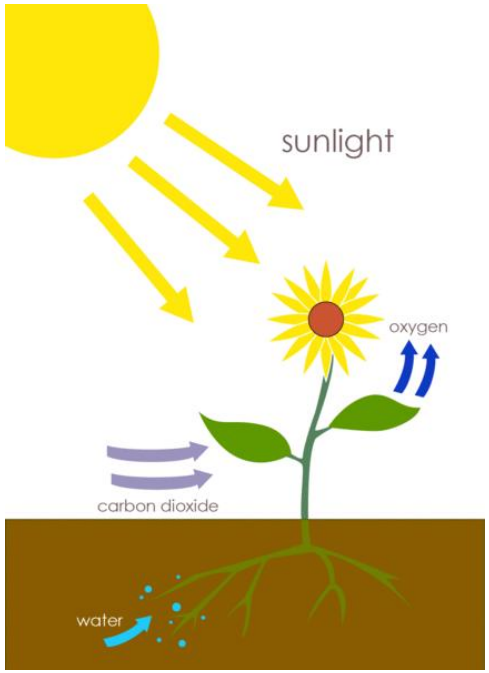
Richard Waring, Oregon State Univ.

NPP from Satellite Data

Methods

- **Photosynthesis is driven by visible light.**
- **Conceptually, GPP in a watered and fertilized plant is a function of the amount of "good" light absorbed (photosynthetically active radiation, APAR).**
- **APAR is a function of radiant energy and leaf area.**



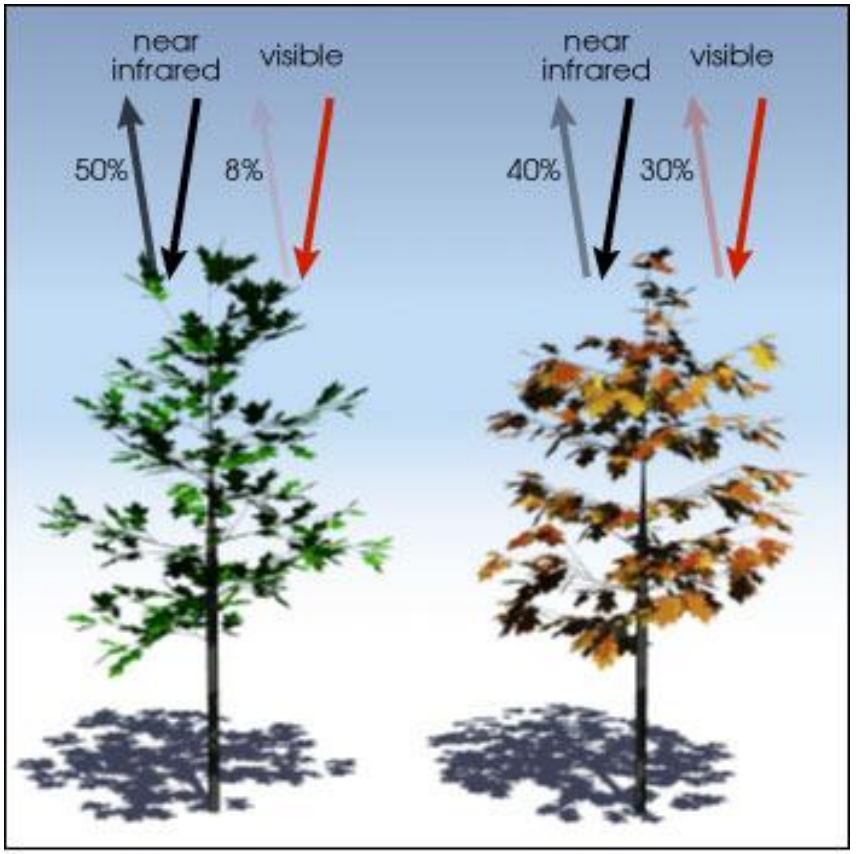


GPP = APAR x Conversion efficiency or E

NPP from Satellite Data

Methods

- **APAR can be estimated from satellites which measure incoming light and reflected light.**
- **NDVI (Normalized difference vegetation index) is based on the ratio of visible (good) and infrared light (not used).**



NDVI = (NIR — VIS)/(NIR + VIS)

NPP from Satellite Data

Methods

- **APAR can be estimated from satellites which measure incoming light and reflected light.**
- **NDVI (Normalized difference vegetation index) is based on the ratio of visible (good) and infrared light (not used).**
- **The key is knowing the fraction of photosyn active light that is absorbed by the plant.**
- **Thus, GPP = NDVI times photosyn active radiation times conversion efficiency, or: GPP = NDVI x PAR x E**

- **NPP = GPP - respiration**

NPP from Satellite Data

Methods

- **APAR can be estimated from satellites which measure incoming light and reflected light.**
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- **Thus, GPP = NDVI times photosyn active radiation times conversion efficiency, or:**

- **GPP = NDVI x PAR x E**

- **NPP = GPP – respiration**

- **E varies with veg type and with climatic constraints and so these are inputs into the model. Nutrients are assumed to influence leaf area and LAI comes from a look up table.**

Global Patterns of NPP from Satellite Data

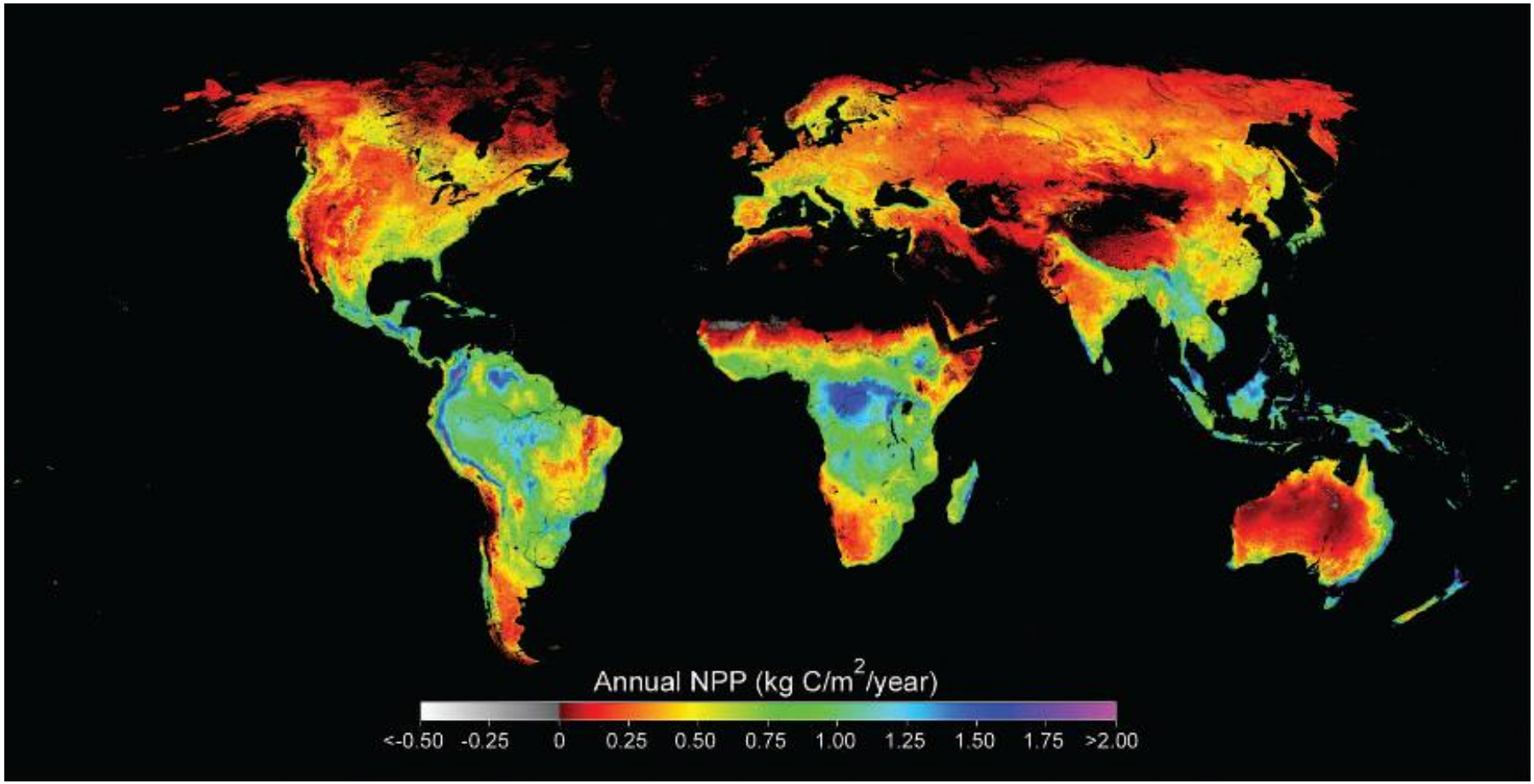


Figure 5. Global terrestrial net primary production (NPP) over 110 million square kilometers for 2002, computed from MODIS (Moderate Resolution Imaging Spectroradiometer) data. Running et al. 2004.

Global Patterns of NPP from Satellite Data

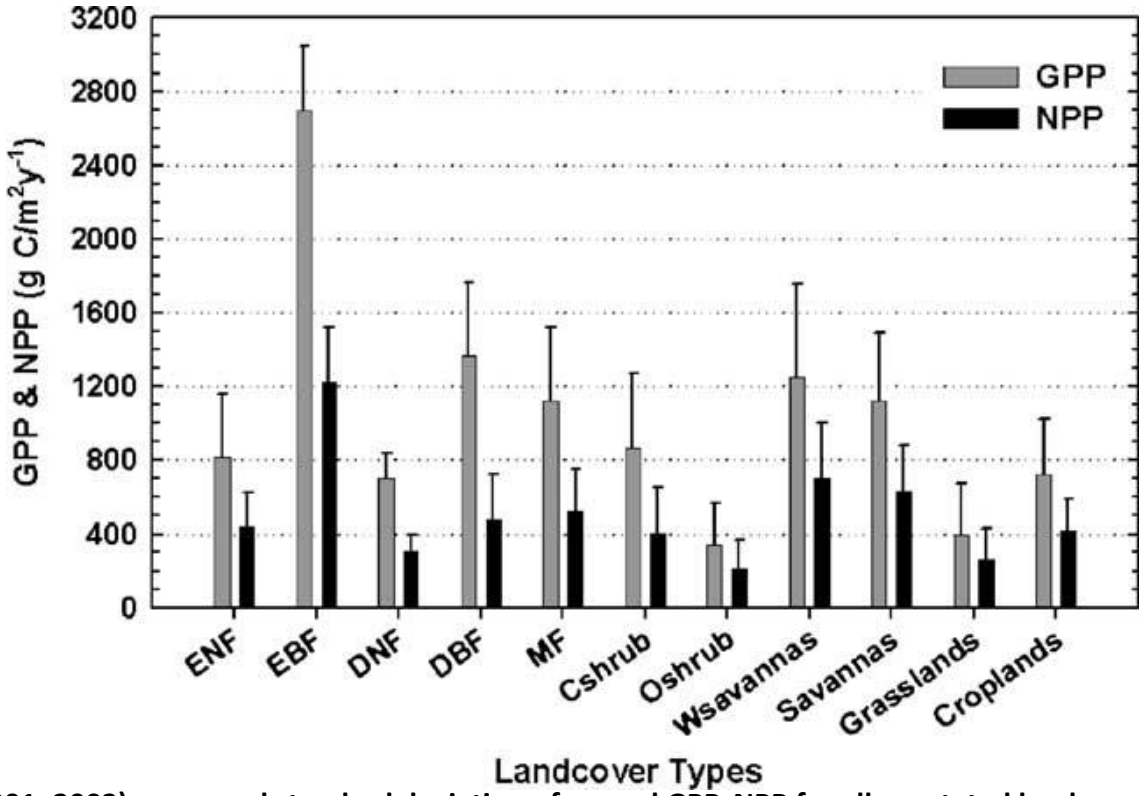


Fig. 7. Three-year (2001–2003) mean and standard deviation of annual GPP, NPP for all vegetated land cover types delineated using MODIS land cover (full name and values for different land cover types are given in Table 1). Zhao et al. 2005.

Table 1
Three-year mean GPP, NPP and the ration of NPP to GPP for different land cover types across the globe

	Evergreen needle forests	Evergreen broadleaf forests	Deciduous needle forests	Deciduous broadleaf forests	Mixed forests	Closed shrublands
GPP (g C/m^2/year)	818	2699	703	1366	1125	868
NPP (g C/m^2/year)	441	1224	301	482	524	405
Ratio (NPP/GPP)	0.54	0.45	0.43	0.35	0.47	0.47

	Open shrublands	Woody savannas	Savannas	Grasslands	Croplands
GPP (g C/m^2/year)	336	1250	1121	396	721
NPP (g C/m^2/year)	212	705	627	259	420
Ratio (NPP/GPP)	0.63	0.56	0.56	0.65	0.58

Global Patterns of NPP from Satellite Data

Table 6.4 Net primary production (NPP) of the major biome types based on biomass harvests[a]

Biome	Aboveground NPP ($g\ m^{-2}\ year^{-1}$)	Belowground NPP ($g\ m^{-2}\ year^{-1}$)	Belowground NPP (% of total)	Total NPP[b] ($g\ m^{-2}\ year^{-1}$)
Tropical forests	1,400	1,100	44	2,500
Temperate forests	950	600	39	1,550
Boreal forests	230	150	39	380 (670)[b]
Mediterranean shrublands	500	500	50	1,000
Tropical savannas/grasslands	540	540	50	1,080
Temperate grasslands	250	500	67	750
Deserts	150	100	40	250
Arctic tundra	80	100	57	180
Crops	530	80	13	610

Chapin et al. 2011.

Huston and Wolverton 2009

“The pattern of terrestrial NPP, based on multiple syntheses and confirmed by satellite images and sophisticated computer models of global vegetation … is [*thought to be*] greatest in tropical rain forests along the equator and declining toward the temperate regions to the north or south. “

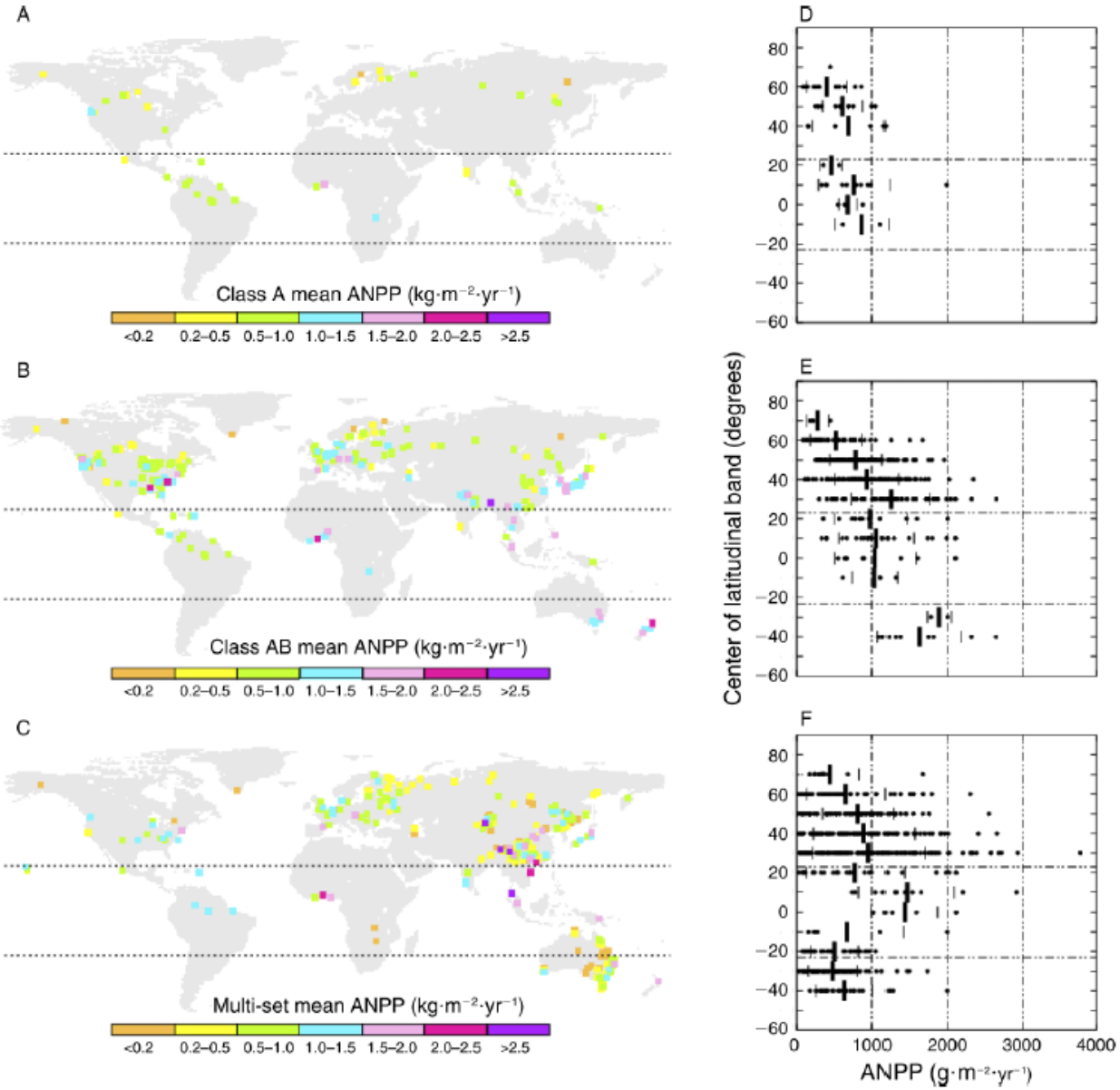
“While temperature and ppt are most favorable in the tropics, they cause soils to be infertile.”

“Are wet tropical forests actually high in NPP?”

Michael Huston, Texas State

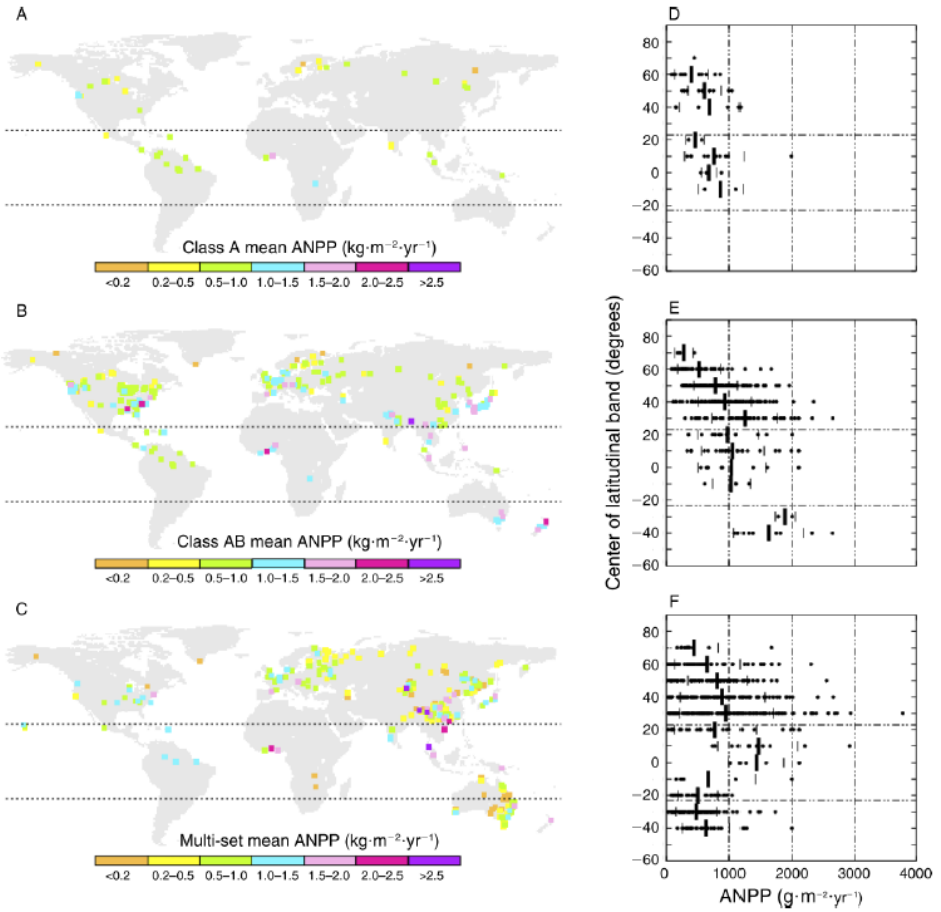
Huston and Wolverton 2009

Field data from various sources.



Huston and Wolverton 2009

"These results, which on average show no difference in annual NPP between temperate and tropical forests are in direct conflict with the global pattern of NPP taught in ecology textbooks and found in the latest modeling results"



Who is Right? Huston and Wolverton or the World?

Humid Tropical

Location	ANPP	NPP	Method	Source
Global tropics (244 sites)		864 +- 96	Field	Luyssaert et al. 2007
Amazonia (10 sites)	596-1088 Mean 746	930-1700 Mean 1280	Field	Aragao et al. 2009
Neotropics (10 sites)	560-960 Mean 687	Low range 670-1150 High range 1220-2120	Field	Clark et al. 2001
Tropical	600-900		Field (Class A sites from ORNL)	Huston and Wolverton 2009
Amazonia		700-1400	MODIS	Zhao et al 2005
Amazonia		800->1100	Regression based on temp	Del Grosso et al. 2008

Humid Temperate Deciduous

Location	ANPP	NPP	Method	Source
Global (244 sites)		738+-55	Field based on 244 sites	Luyssaert et al. 2007
Walker Branch, TN	540		Field	Curtis et al. 2002
Harvard Forrest, NH, 60 yr	300		Field	Curtis et al. 2002
Indiana, 80 yrs	529		Field	Curtis et al. 2002
MichiganI 90 yr	338		Field	Curtis et al. 2002
Wisconsin 66 yrs	300		Field	Curtis et al. 2002
Wisconsin 100+ yrs	750			Reich et al. 1997
Global	450-750		Field	Huston and Wolverton 2009
Eastern NA		500-700	MODIS	Zhao et al 2005

Who is Right? Huston and Wolverton or the World?

My Conclusions

- **Straight up comparison of NPP among places and biomes is very problematic due to different methods, forest ages, and plain inconsistencies.**

- **NPP is ca 17% higher in the humid tropics than the humid temperate zone but may not be statistically significant due to high variability.**

- **Huston and Wolverton overstate slightly their conclusion that there is no evidence of higher annual NPP in the humid tropics and the temperate humid zones (and they offer no statistical evidence).**

- **MODIS might get the range of annual NPP right in the humid tropics (but is not sensitive to the important differences in soil fertility between the neotropics, Africa, and Asia), but might be a bit low for the EDF in the North America.**

- **Surprising and lots of work needs to be done.**

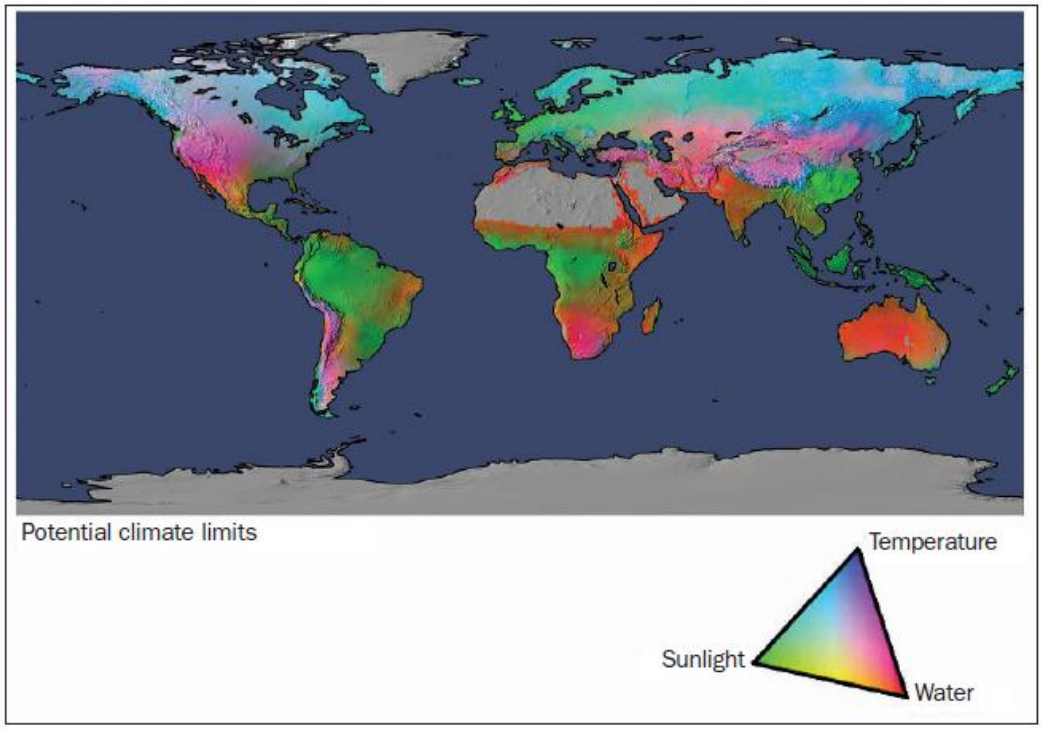
Who is Right? Huston and Wolverton or the World?

How does Chapin et al. say about how NPP could be high in the tropics despite infertile soils?

Implications of Global Patterns of NPP

Response to Climate Change

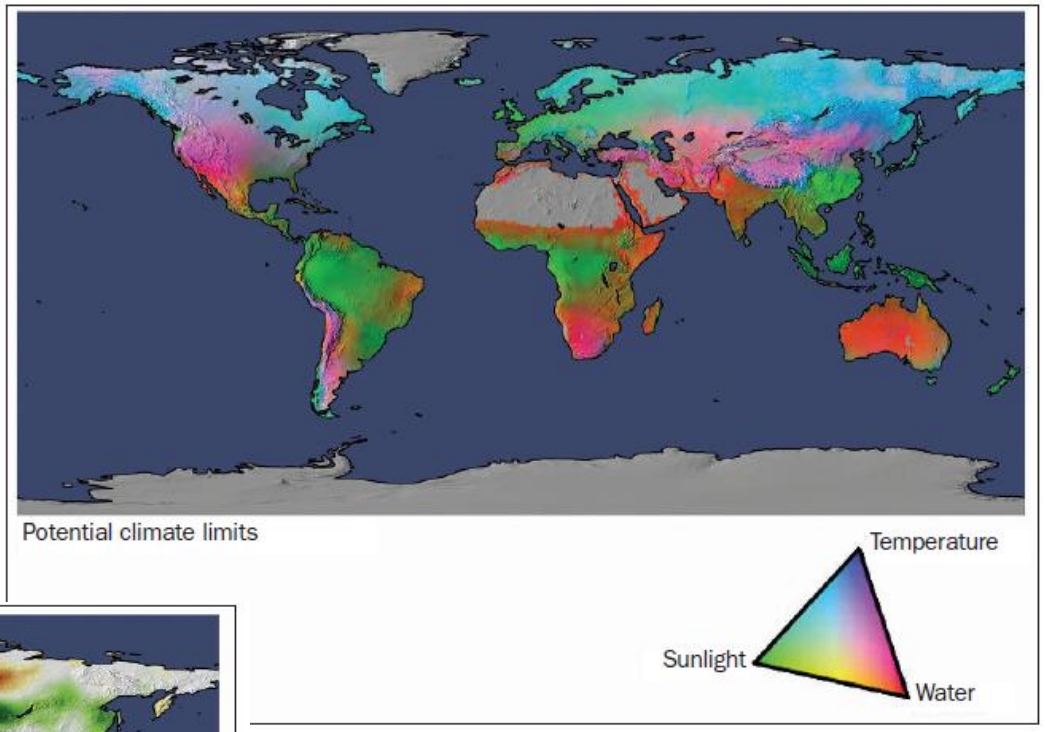
What are the implications of spatial variation in controlling factors for NPP response to climate change?

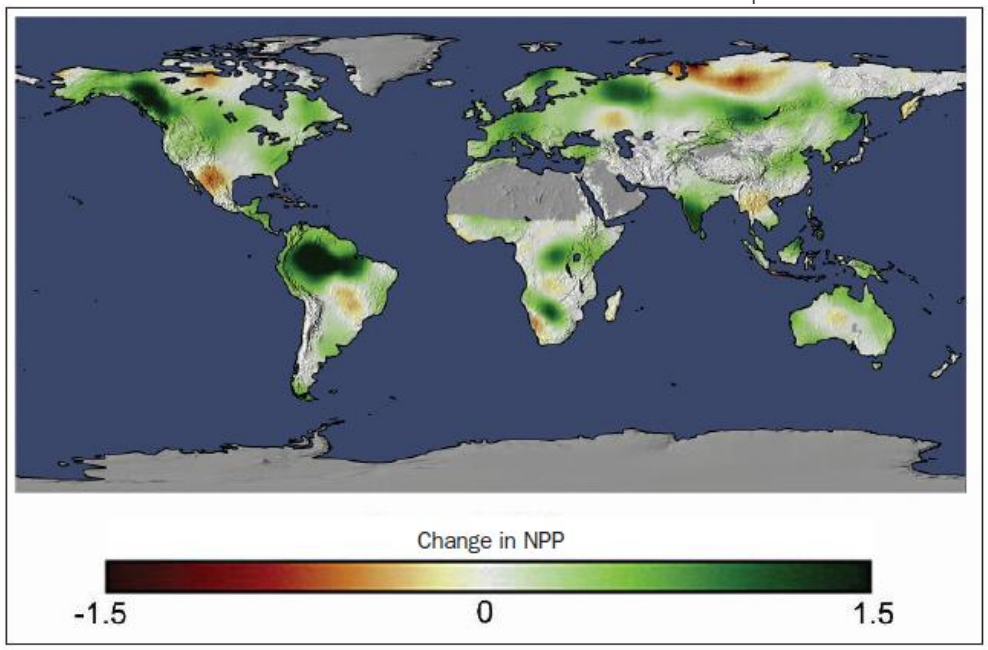


Running et al. 2004 Figs 1 and 3

Implications of Global Patterns of NPP

Response to Climate Change



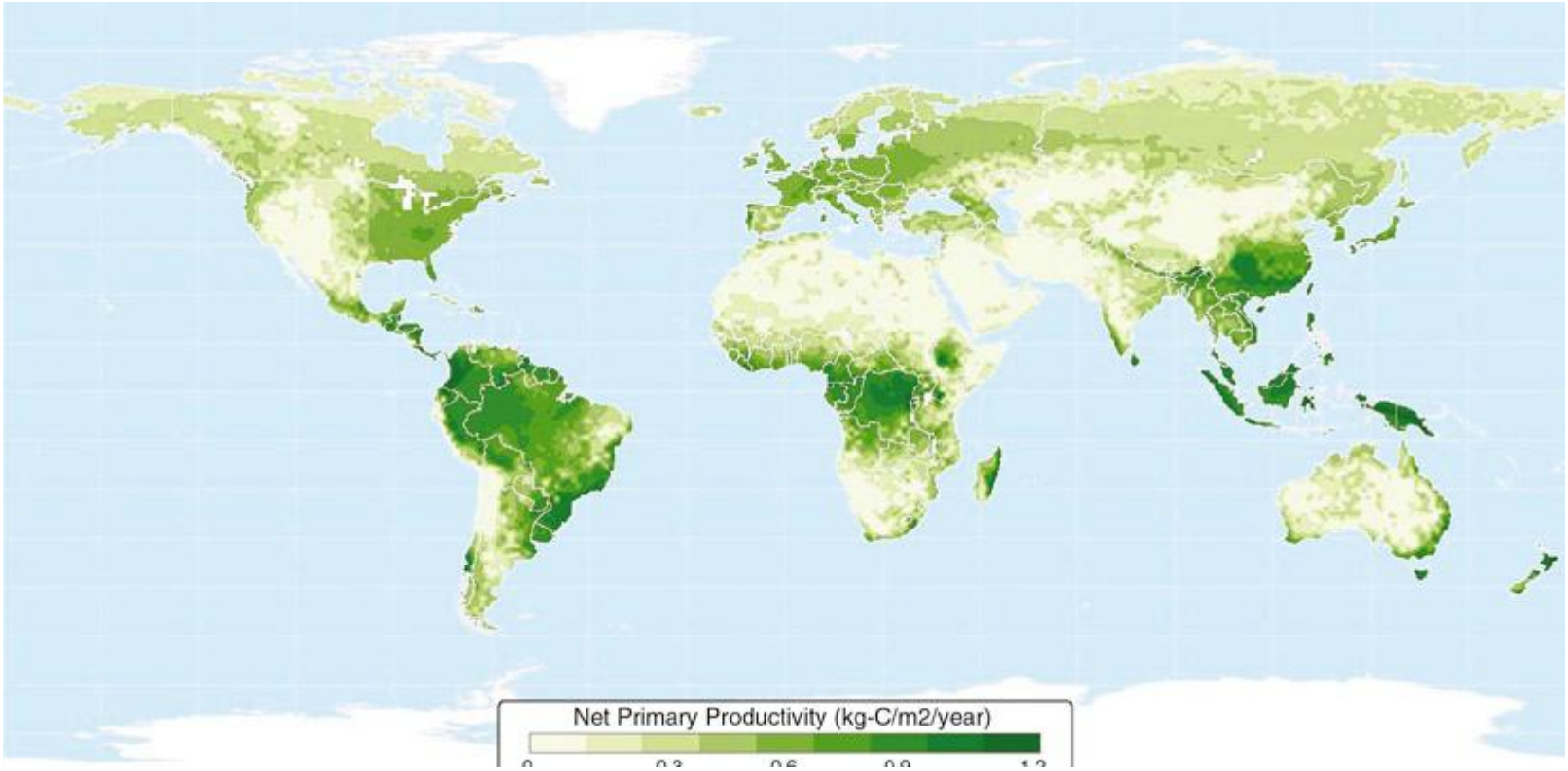


1981-1999

Running et al. 2004 Figs 1 and 3

Implications of Global Patterns of NPP

Food Quantity and Quality to Herbivores and higher Tropic Levels

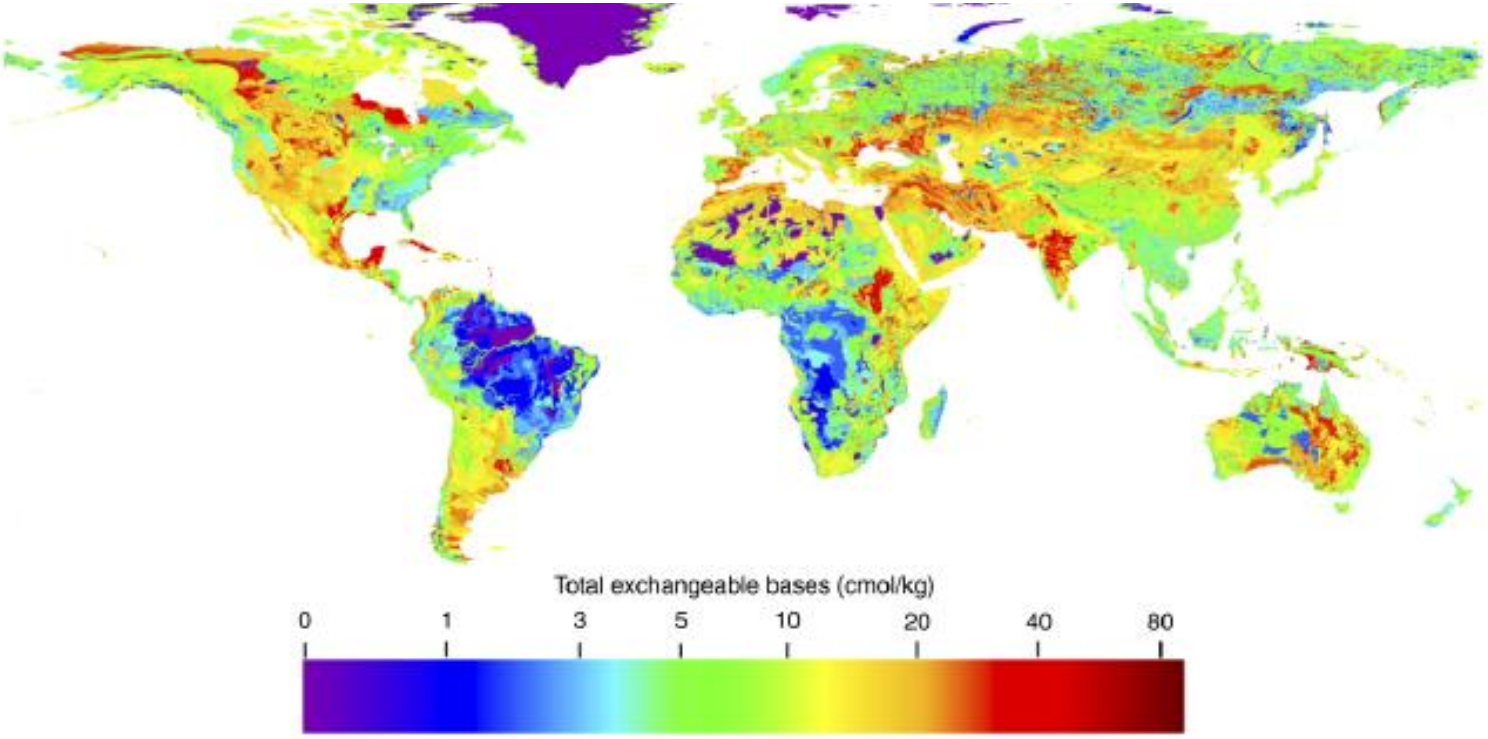


Chapin et al. 2011 Figs 6.2

How might plant quality vary with soil fertility in the humid tropics based on the strategies plants use to cope with resource limitations according to Chapin et al.?

Implications of Global Patterns of NPP

Agricultural Productivity



Huston and Wolverton 2009 Fig 4

What are the implications of NPP and soil nutrient patters for agricultural productivity in the tropics?

References

Scurlock, J.M.O. and R.J. Olson. 2002. Terrestrial net primary productivity: A brief history and a new worldwide database. Environmental Reviews 10: 91–109.

Zhao, M., F. A. Heinsch, R. R. Nemani, and S. W. Running. 2005. Improvements of the MODIS terrestrial gross and net primary production global data set. Remote Sensing of Environment 95:164–176.