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.
How does NPP vary from place to place?

- Tree allometry and diameter increment in a stand.

- Compile many stand estimates and average within biomes


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.
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
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).

\[
\text{NDVI} = \frac{(\text{NIR} - \text{VIS})}{(\text{NIR} + \text{VIS})}
\]
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, $GPP = NDVI \times \text{photosyn active radiation} \times \text{conversion efficiency}$, or: $GPP = NDVI \times PAR \times E$

• $NPP = GPP - \text{respiration}$
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:

  \[ \text{GPP} = \text{NDVI} \times \text{PAR} \times E \]

- 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.
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.
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.
Global Patterns of NPP from Satellite Data

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

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

-Chapin et al. 2011.
“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?”
Field data from various sources.
“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”
### Humid Tropical

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

### Humid Temperate Deciduous

<table>
<thead>
<tr>
<th>Location</th>
<th>ANPP</th>
<th>NPP</th>
<th>Method</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global (244 sites)</td>
<td>738+-55</td>
<td>Field based on 244 sites</td>
<td>Luyssaert et al. 2007</td>
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<tr>
<td>Walker Branch, TN</td>
<td>540</td>
<td>Field</td>
<td>Curtis et al. 2002</td>
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</tr>
<tr>
<td>Harvard Forrest, NH, 60 yr</td>
<td>300</td>
<td>Field</td>
<td>Curtis et al. 2002</td>
<td></td>
</tr>
<tr>
<td>Indiana, 80 yrs</td>
<td>529</td>
<td>Field</td>
<td>Curtis et al. 2002</td>
<td></td>
</tr>
<tr>
<td>Michiganl 90 yr</td>
<td>338</td>
<td>Field</td>
<td>Curtis et al. 2002</td>
<td></td>
</tr>
<tr>
<td>Wisconsin 66 yrs</td>
<td>300</td>
<td>Field</td>
<td>Curtis et al. 2002</td>
<td></td>
</tr>
<tr>
<td>Wisconsin 100+ yrs</td>
<td>750</td>
<td></td>
<td>Reich et al. 1997</td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>450-750</td>
<td>Field</td>
<td>Huston and Wolverton 2009</td>
<td></td>
</tr>
<tr>
<td>Eastern NA</td>
<td>500-700</td>
<td>MODIS</td>
<td>Zhao et al 2005</td>
<td></td>
</tr>
</tbody>
</table>
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?
What are the implications of spatial variation in controlling factors for NPP response to climate change?
Implications of Global Patterns of NPP

Response to Climate Change

Running et al. 2004 Figs 1 and 3

Change in NPP

-1.5  0  1.5
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.?
What are the implications of NPP and soil nutrient patterns for agricultural productivity in the tropics?