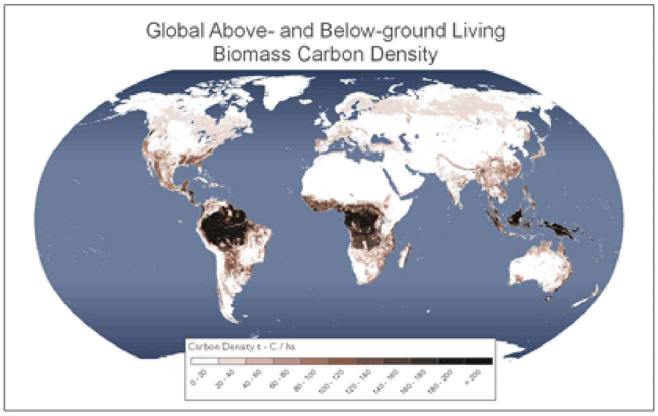
New IPCC Tier-1 Global Biomass Carbon Map for the Year 2000



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ABSTRACT

Here we present a new global map of biomass carbon stored in above and belowground living vegetation created using the International Panel on Climate Change (IPCC) Good Practice Guidance for reporting national greenhouse gas inventories. This map provides important

benchmarks for climate policy dialogues aiming to reduce carbon emissions from land-use change, and may also advance global terrestrial and climate modeling efforts by providing improved representation of global vegetation carbon stocks.

INTRODUCTION

Maps of vegetation biomass carbon density are important for quantifying terrestrial carbon sinks as well as potential emissions to the atmosphere from land-use change. Worldwide, living vegetation stores an enormous 500 billion tones of carbon, more than 60 times annual anthropogenic carbon emissions to the atmosphere. The tropics and sub-tropics combined store 430 billion tones of carbon, while boreal and temperate ecoregions store 34 billion tones and 33 billion tones, respectively.

The importance of these vegetation carbon stores to mitigating climate change is getting increasing attention in national and international climate policy discussions (Gibbs and Herold 2007). In particular, the importance of Reducing Emissions from Deforestation and Degradation (REDD) in developing countries has recently gained momentum under the United Nations Framework on Climate Change (Gullison et al 2007). Widely accepted methods to estimate and report national-level greenhouse gas emissions from land use change have been established by the International Panel on Climate Change (IPCC). The IPCC Good Practice Guidance (Penman et al 2003) and Greenhouse Gas Inventory Guidelines (IPCC 2006) provide recommendations on methods and default values for assessing carbon stocks and emissions at three tiers of detail, ranging from Tier 1 (simplest to use; globally-available data) up to Tier 3 (highresolution methods specific for each country and repeated through time).

Here we have synthesized and mapped the IPCC Tier-1 default values using a global land cover map stratified by continent, ecoregion and forest disturbance-level.

This is the first database to provide a globally-consistent and spatially-explicit estimate of vegetation carbon stocks, circa 2000, following the IPCC standardized methodology. Several other spatial databases provide estimates of global vegetation carbon stocks for potential vegetation (Olson et al. 1983), conditions circa 1990 (WRI 2000) or 2000 (Gibbs 2006) but with very coarse land cover classification. Regional vegetation carbon maps also exist for the Brazilian Amazon (Saatchi et al 2007), tropical Africa (Brown and Gaston 1995, 1996, Gibbs and Brown 2007a) and Southeast Asia (Brown et al. 1993, 2001, Gibbs and Brown 2007b).

This new dataset provides key starting points for climate policy negotiations and decisions by allowing globally-consistent estimates of the amount of carbon stored in living above and below ground vegetation at regional, national, and sub-national scales. This database can also be used in land-use, biogeochemical and climate models to answer key questions about on-going climate change and carbon emissions. See Gibbs et al (2007) for review of key steps to improve estimate of carbon stocks, especially across the tropics.

METHODS

We created the vegetation biomass carbon database following two main steps: 1) estimate carbon stocks, and 2) map values using a range of spatially-explicit climate and vegetation datasets.

We followed the IPCC GPG Tier-1 method for estimating vegetation carbon stocks using the globally consistent default values provided for aboveground biomass (IPCC 2006). We added belowground biomass (root) carbon stocks using the IPCC root to shoot ratios for each vegetation type, and then converted total living vegetation biomass to carbon stocks using the carbon fraction for each vegetation type (varies between forests, shrublands and grasslands). All estimates and conversions were specific to each continent, ecoregion and vegetation type (stratified by age of forest). Thus, we compiled a total of 124 carbon zones or regions with unique carbon stock values based on the IPCC Tier-1 methods. Please refer to Tables 1a-i to review the details associated with each of these carbon zones. A small number of carbon zones were not included in the original IPCC default data but were in the land cover map such as mixed and burnt forest and natural vegetation/cropland mosaic categories. These special instances are described in more detail below.

We then mapped these unique carbon zones using the following spatial datasets of global land cover, continental regions, ecofloristic zones and forest age:

- The vegetation map from the Global Land Cover 2000 Project (GLC2000) based on SPOT-VEGETATION satellite imagery for the year 2000 was used to identify the actual vegetation type (e.g., forest, grassland, shrubland, cropland, mosaics, and desert, etc.). The GLC2000's classification scheme is widely accepted, and was selected as the core dataset for the Millennium Ecosystem Assessment. It has a 1km native spatial resolution and classifies the Earth's land cover into 23 categories (Figure 1).

- For continental regions, we developed a polygon coverage that divides the globe into 7 continental regions plus all oceanic island zones (Figure 2). This was a simple process of drawing outlines around primary continental landmasses and their associated islands. Some of the islands that were included were relatively isolated from the larger region (e.g. the Canaries, the Galapagos), so we are left to assume that their climate and vegetation types are similar enough to the main land masses to be put in the same continental region. (continental_regions.zip)
- For climatic or ecoregions zones, we used a map that identifies major global ecofloristic zones developed by the Food and Agriculture Organization (FAO), which was also used by the IPCC to categorize the carbon stock estimates (Figure 3). Each of the 20 ecoregions are characterized by their temperature regime (tropical, subtropical, temperate, boreal, and polar) and their vegetation type (humid forest, dry forest, moist deciduous forest, shrubland, steppe, desert, etc.). For defining forests and shrublands, the IPCC tables use the exact same ecoregion designation as the FAO. For grasslands however, the IPCC only used climate and precipitation descriptors (tropical moist & wet, tropical dry, temperate wet, temperate dry, etc.), so in some cases we aggregated ecoregions together. (ecofloristic_zones.zip)
- We used a map of frontier forests which are defined as relatively unmanaged forests with little human disturbance, to identify forest age because the IPCC distinguishes old and young forests in some regions (Figure 4) (Bryant et al. 1997). (frontier_forests.zip)

The continental regions, ecofloristic zones, and frontier forest shapefiles were combined to determine the spatial distribution of global carbon_zones. These data were then gridded and combined with the GLC2000 data. An ESRI ArcInfo script was used to apply the associated carbon values to each pixel within a carbon zone. Specifically, we clipped out the carbon zone boundaries from the GLC2000 gridded land cover data and then used a series of carbon remap tables, created from the values listed in tables 1a-1i, to assign carbon values to the gridded data. These clipped GLC2000 carbon zone grids were then merged back together to form a single contiguous global dataset at 1 kilometer by 1-kilometer resolution.

We developed several decision-rules and occasionally used "best guesses" in developing the script and mapping the carbon values. Major decision-rules are described below, while more detailed assumptions are footnoted in Tables 1a-i.

- Most of the carbon mapping relied on the GLC2000 satellite-based land cover map; the other maps only serve to provide additional qualifying information for the vegetation classes depicted in GLC2000. Thus GLC2000 generally trumped all other datasets where disagreement occurred. For example, if a GLC2000 forest pixel fell within an FAO desert ecofloristic zone, the pixel was still assigned forest as identified by GLC2000.
- Occasionally missing information from the IPCC or from the four input vegetation maps required aggregating different carbon zones together. For example, IPCC values for wet and dry grasslands were averaged and applied across all GLC2000 grasslands because it wasn't possible to distinguish dry and wet grasslands with our input datasets. Also, IPCC did not provide a carbon value for the GLC2000 mixed forest category so we averaged the appropriate broadleaved and needle-leaved carbon values.
- GLC2000 identified disturbed vegetation categories, such as burnt forests or cropland mosaics, which were not specified by the IPCC Tier-1 methods. In these cases, we assigned 50% of the non-disturbed carbon value for the corresponding class as defined by IPCC. For example, GLC2000 cropland mosaic or sparse vegetation classes were given one half the value of the non-cropland or dense land-cover type. Similarly, forest-cropland mosaic and burnt forest were assigned half the forest value. Also note that when forest-cropland mosaic fell in frontier forest they were assigned half the carbon value for non-frontier forests.

The resulting global gridded dataset depicts vegetation biomass carbon stocks at the native processing resolution of 0.0089 decimal degrees (~1km by ~1km). We used the mean aggregate ArcInfo command to resample this dataset to 5 and 10 minute spatial resolution (please note that the 10 minute data includes the extent of Antarctica, while the others do not). The 1km data is expressed in 0.01 tonnes of biomass carbon per hectare, while the 5 and 10 minute data are expressed in tonnes of biomass carbon per hectare; soil carbon stocks are not included. Each map is geo-referenced to the WGS1984 coordinate system, and in geographic projection.

DATA FILE LISTING

- continental_regions.zip: zipfile contains components of continental regions shapefile
- ecofloristic_zones.zip: zipfile contains components of ecofloristic zones shapefile

- frontier_forests.zip: zipfile contains components of frontier forests shapefile
- glc2000.zip: zipfile contains ARC/INFO GRID export file of GLC2000
- carbon_zones.zip: zipfile contains components of carbon zones shapefile
- code.zip: zipfile contains ARC/INFO GRID export file of carbon zones prior to the assignment of carbon values
- lut.zip: zipfile contains Microsoft Excel spreadsheet of carbon values associated with land cover classes. Please note that the html version of these data includes root:shoot values and carbon fraction values. CDIAC included these values to enhance the documentation of this dataset. These additional values are not listed in the Excel files.
- remap_tables.zip: zipfile contains remap/lookup tables used to assign carbon values to pixels
- datasets.zip: zipfile contains ARC/INFO grid directory structure for output GRIDS including: c_1km, c_5m, and c_10m (0.01 t -C/ha at 1km, and t -C/ha at 5 minute and 10 minute resolutions)
- images.zip: zipfile contains graphic files representing figures 1-5

DATA CAVEATS AND LIMITATIONS

This spatial database is likely the best available, globally-consistent map depicting vegetation carbon stocks, circa 2000, and follows the widely accepted IPCC methods for estimating carbon stocks at the national level. However, the methods employed here are not directly linked to ground-based measures of carbon stocks and have not been validated with field data. We essentially applied a sophisticated paint-by-numbers approach, which consequently masks variations within classes and may lead to unnatural, abrupt gradients between vegetation classes as defined by the GLC 2000 and FAO ecoregions (Gibbs et al. 2007).

For example, our approach does not account for different vegetation conditions that could lead to lower or higher carbon stocks, such as logged, regrowing, or virgin ecosystems. Similarly, croplands received the same carbon stock value regardless of the type of crop that might be growing, which is clearly a simplification. The same IPCC default carbon value was applied to all vegetation within each broad class regardless of condition. This means that the actual carbon storage in a given location could be more or less than indicated by our map.

Similarly, there are several areas where abrupt, likely unrealistic, transitions exist due to the categorical nature of the GLC2000 dataset, which does not allow smooth blending between land cover classes. This issue is most evident along the shrubland / grassland interface. According to the IPCC (2006), shrubland stores much more carbon than grassland, which may not be true across vegetation transition zones. In certain pronounced regions, such as the interior desert of Australia, this difference is especially noticeable. Abrupt transitions also occur occasionally at the boundaries of ecoregions where spurious jumps in carbon values occur as a result of a change in ecoregion definition this occurs most notably in the Guayana Highlands in Venezuela and in the Ural Mountains, where the ecoregions changes from non-mountainous to mountainous.

TABLES

Tables 1a-i: Global biomass carbon look-up tables for broad vegetation classes stratified by ecoregions, continent and vegetation age (frontier vs. non-frontier), based on the IPCC guidelines for estimating national-level carbon stocks. Please note that CDIAC has included the root:shoot and carbon fraction values used by the data authors, to enhance the documentation. These values are not included in the Excel spreadsheets provided by the data authors.

- Table 1a. Broadleaf Forest Classes (GLC2000 classes 1-3)
- Table 1b. Evergreen Forest Classes (GLC2000 classes 4&5)
- Table 1c. Mixed Forest Classes (GLC2000 classes 6-8)
- Table 1d. Burnt Forest and Natural Forest Mosaic (GLC2000 classes 9&10)
- Table 1e. Forest/Cropland Mosaic (GLC2000 class 17)
- Table 1f. Shrub Cover (GLC2000 classes 11,12&15)
- Table 1g. Grasslands (GLC2000 class 13)
- Table 1h. Sparse Grassland and Grassland Mosaic (GLC2000 classes 14&18)
- Table 1i. Other Classes (GLC2000 classes 16,19,20-23)
- Footnotes

FIGURES

Figure 1: Global land cover database for the year 2000. Based on SPOT-VEGETATION satellite imagery collected at 1km by 1km spatial resolution.

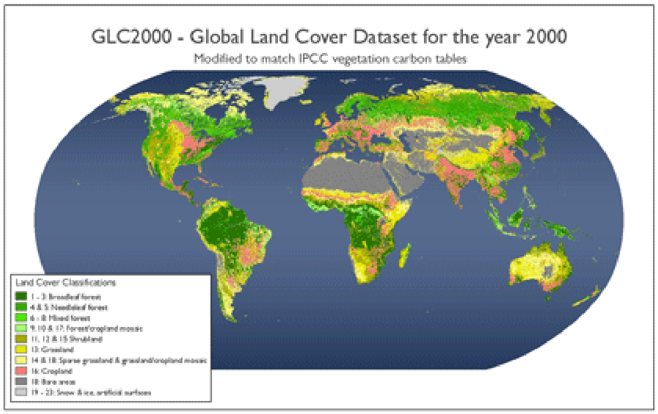


Figure 2: Continental regions created by authors in ESRI ArcGIS.

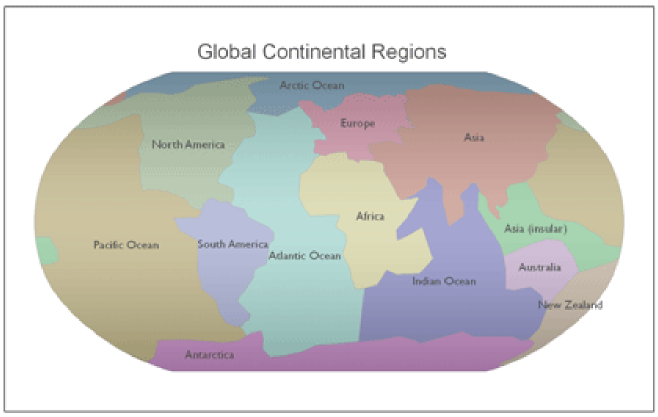


Figure 3: Global ecofloristic zones mapped by the United Nations Food and Agricultural Organization.

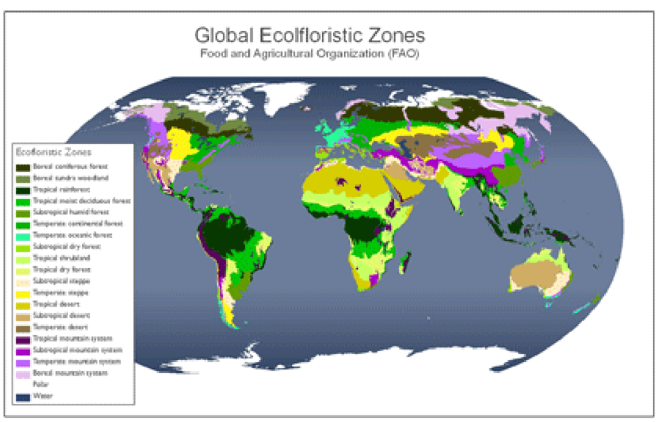
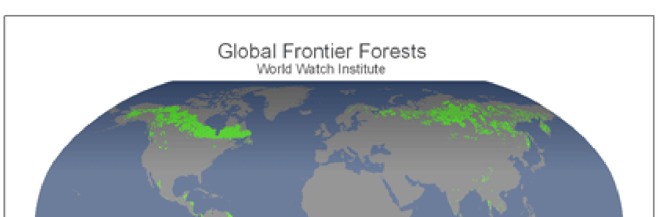


Figure 4: Locations of frontier forest, which are likely to be > 20 years old, relatively undisturbed by humans and largely shaped by natural forces (Bryant et al. 1997).



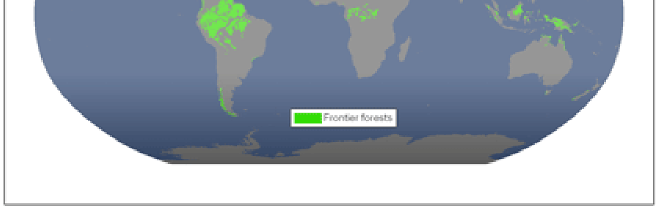
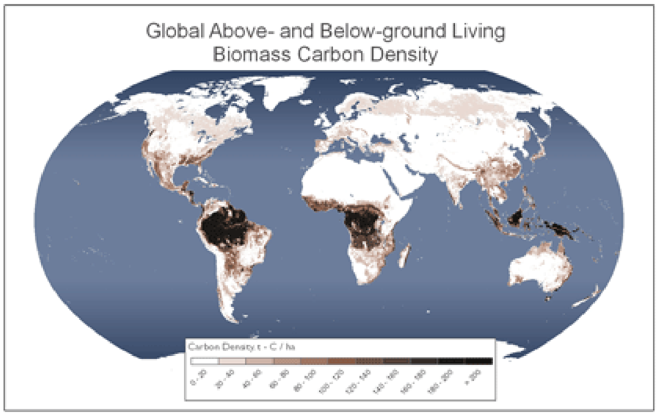


Figure 5: Final map of global vegetation carbon stocks.



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