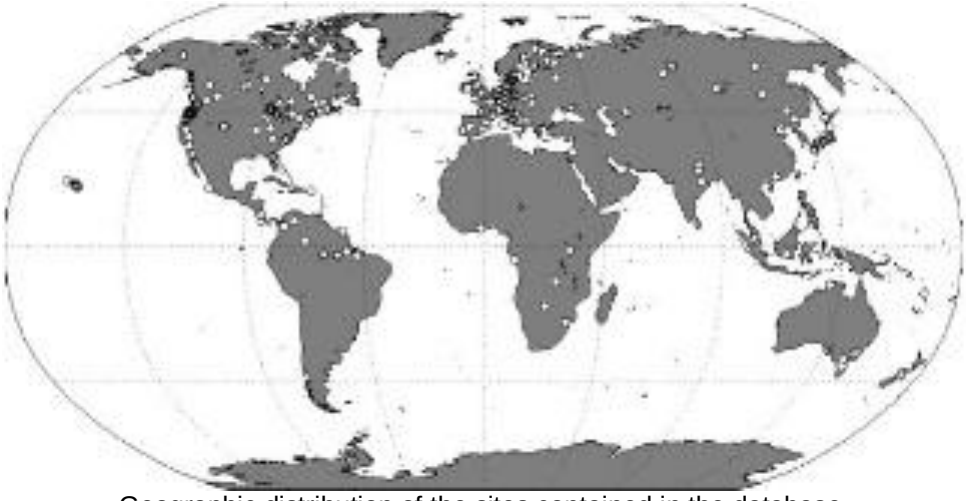
Global Forest Ecosystem Structure and Function Data for Carbon Balance Research

Abstract

A comprehensive global database of forest ecosystem carbon budget variables (fluxes and stocks), ecosystem traits (standing biomass, leaf area index, age), and ancillary information (management regime, climate, soil characteristics) has been compiled for 528 sites. The data set includes: a Microsoft Office Access Database (Version 2003); data files for all tables in the database in *.csv format; and query outputs from the database in *.csv format.

This database facilitates the quantification of CO2 fluxes and pathways across different levels of integration (from photosynthesis to net ecosystem production) in forest ecosystems. The database fills an important gap for model calibration, model validation, and hypothesis testing at global and regional scales (Luyssaert et al. 2007).

This database is structured by site (i.e., a forest or stand of known geographical location, biome, species composition, and management regime). It contains carbon budget variables (fluxes and stocks), ecosystem traits (standing biomass, leaf area index, age), and ancillary information (management regime, climate, soil characteristics) for 528 sites from eight forest biomes. Data entries originated from peer-reviewed literature and personal communications with researchers involved in FLUXNET. Flux estimates were included in the database when they were based on direct measurements (e.g., tower-based eddy covariance system measurements), derived from single or multiple direct measurements, or modeled. Stand description was based on observed values, and climatic description was based on the East Anglia Climate research Unit (CRU) data set and ORCHIDEE model output. Uncertainty for each carbon balance component in the database was estimated in a uniform way by expert judgment. Robustness of CO2 balances was tested. Unmeasured components of the carbon balance were calculated by difference to close the budgets. These closure terms provide an estimate of data quality and flux uncertainty.



Geographic distribution of the sites contained in the database.

Nomenclature Used in This Documentation File

ANPP = aboveground net primary production
BNPP = belowground net primary production
GPP = gross primary production
NEP = net ecosystem production
NPP = net primary production
R_a = autotrophic respiration
R_e = ecosystem respiration
R_h = heterotrophic respiration
R_s = soil respiration
VOC = volatile organic compounds
TNPP = Total net primary production

Background Information

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See Appendix A for the names, postal addresses and email addresses of researchers who contributed data to this database as well as a list of published and unpublished data sources contained in the database.

Data Set Title: Global Forest Ecosystem Structure and Function Data for Carbon Balance Research

Site: Global

Westernmost Longitude:	-159.5 W
Easternmost Longitude:	172.75 E
Northernmost Latitude:	67.36 N
Southernmost Latitude:	-42.87 S

Data Set Citation:

Luyssaert, S., I. Inglima and M. Jung. 2008. Global Forest Ecosystem Structure and Function Data for Carbon Balance Research. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. doi:10.3334/ORNLDAAC/949

If you use this database, please also reference:

Luyssaert S, I. Inglima, M. Jung et al. 2007. The CO_2-balance of boreal, temperate and tropical forests derived from a global database. Global Change Biology, 13: 2509-2537.

Data File Information:

This database archive includes (1) a Microsoft Office Access Database (Version 2003) ; (2) exported files for all data tables in the database, in .csv format; and (3) exported view data (queries) from the database, in .csv format.

Microsoft Office Access Database – A comprehensive relational database structure was designed using Microsoft Office Access (Version 2003) to store information on carbon fluxes, ecosystem properties, and site information for forest stands. Each site in the database is linked to at least one carbon balance component and each component is further linked to the methodology that was used to estimate it.

The database file <Literature_compilation_3.1_mdb.zip> is zip compressed; uncompressed it is 263.8 MB in volume.

Exported Files for All Data Tables in the Database (.csv format) – All of the data tables in the database have been exported and saved as .csv files. The exported data files are compressed and provided in one file <forest_carbon_flux_data.zip>. The types of data tables, file names, and file contents are shown below. Also see the documentation file <Documentation_literature_compilation_v3.1.pdf> for additional notes, flags, and other information pertaining to the data tables.

- Please be advised that the database and exported tables are structured by plot (site). All level 3 and 4 tables are linked by the field 'Plot name' to the <1_Site_information.csv> table. Note that in the level 3 and 4 tables this field is named 'Plot'. The exception is table <4_Site_labels.csv> where the field is named 'Site name'.
- Please note that in the level 2 methodology tables, the key field is 'Methodology number' but in the level 3 tables this field is called 'Methodology'.

(1) Site Information for 528 Sites

<1_Site_information.csv>		
Plot name	Text	Name of the plot according to CarboEurope-IP, Ameriflux, FLUXNET or publication.
Climatic region	Text	Climatic region according to the U.S. Dept. of Agriculture, Natural Resources Conservation Service. The biome classification distinguishes eight forested biomes: boreal humid, boreal semi-arid, temperate humid, temperate semi-arid, Mediterranean warm, Mediterranean cold, tropical humid and, tropical semi-arid sites. Sites are classified according to their geographical location.
Needles/Leaves	Text	Indicate whether the tree species are needle leaved, broadleaved or a mixture of both form.
Evergreen/ Deciduous	Text	Indicate whether the growth strategy of the tree species is evergreen, deciduous or a mixture of both strategies.
Tree species 1	Text	Dominant tree species of the stand.
Tree species 2	Text	Co-dominant tree species of the stand.
Latitude	Number	Latitude in decimal degrees. Indicate South with – & North with +. Decimal degrees were used to ease plotting graphs with latitude on an axis.
Longitude	Number	Longitude in decimal degrees. Indicate West with – & East with +. Decimal degrees were used to ease plotting graphs with longitude on an axis.
Elevation	Number	Elevation above sea level in m.
Management code	Text	2 characters indicating type of management: NI (No Information), M (Managed), UM (Unmanaged), RD (Recently disturbed), FI (Fertilized and/or Irrigated), PO (Polluted).
Management	Text	Relevant information on management and disturbance.
Source 1, 2 & 3	Text	Website or publication where the plot information is available

(2) Methodologies for Carbon Flux Components

<2_Methodology_GPP_NEP_Reco.csv>		
Methodology number	Number	Unique number within this table, this number is used to describe the methodology in the level 3 tables
Eddy covariance	Yes/No	Indicate whether eddy covariance measurements were used to estimate GPP, NEP and/or NEP
Specific parameters	Yes/No	Indicate whether site-specific parameters were available for the model

NPP, biomass, Reco measurements	Yes/No	Indicate whether independent measurements of NPP, biomass, Reco, etc were used to test the model output
NEP	Text	Describe the method that was used to estimate the NEP i.e., Eddy covariance, NPP-direct measurements of R_h, model (with name of the model), etc.
NEP_method	Number	Method-specific reduction factor of total uncertainty of NEP. See Table 1 below.
Reco	Text	Describe the method that was used to estimate the Reco i.e. Ecosystem respiration based on night time respiration vs soil or air temperature relationship, direct measurement of the components of Reco with chambers, model (with name of the model), etc.
Reco_method	Number	Method-specific reduction factor of total uncertainty of Reco. See Table 2 below.
GPP	Text	Describe the method that was used to estimate the GPP i.e., NEP + estimated R_e, NPP + direct measurements of R_a, model (with name of the model), etc.
GPP_method	Number	Method-specific reduction factor of total uncertainty of GPP. See Table 1 below.
Source	Text	Website or publication where the methodology is given

Table 1. Reduction Factors for GPP, NPP, and NEP

<2_GPP_NPP_NEP_Reduction_factor.csv>				
Method	GPP	NPP	NEP	Reduction factor
Eddy covariance and data assimilation	x		x	0.2
Eddy covariance based	x		x	0.3
Measured increment and litterfall		x		0.3
Measured and modeled increment and litterfall		x		0.6
Process-model based	x	x	x	0.6
Flux components based	x	x	x	1.0
Notes: The method-specific reduction factors for GPP, NPP and NEP were determined by expert judgment. The reduction factors account for the precision of a method and were used to reduce the initial variability.				

Table 2. Reduction Factors for R_e, R_s, R_h, and R_a

<Re_Rs_Rh_Ra_Reduction_factor.csv>					
Method	R_e	R_s	R_h	R_a	Reduction factor
Eddy covariance	x	x			0.3
Chamber based		x			0.4
Process-model based	x				0.6
Chamber + girdling			x		0.8
Chamber + root excised			x		0.8
Chamber + trenching			x		0.8
Radiocarbon			x		0.8
Chamber based				x	0.8
Alkali absorption		x			0.8
Chamber + gap based			x		0.9
Process-model based		x	x	x	1.0
Flux component based		x	x	x	1.0
Notes: The method-specific reduction factors for R_e, R_s, R_h and R_a were determined by expert judgment. The reduction factors account for the precision of a method and were used to reduce the initial variability.					

<2_Methodology_NPP.csv>		
Methodology number	Number	Unique number within this table, this number is used to describe the methodology in the level 3 tables
Foliage	Yes/No	Indicate whether foliage production is included in the NPP estimate
Stem	Yes/No	Indicate whether stem production is included in the NPP estimate
Coarse roots	Yes/No	Indicate whether coarse root production is included in the NPP estimate
Coarse root methodology	Text	Describe the method used to estimate the coarse root NPP i.e. allometric relationships, sequential coring, in-growth cores, etc.
Fine roots	Yes/No	Indicate whether fine root production is included in the NPP estimate
Fine root methodology	Text	Describe the method used to estimate the coarse root NPP i.e., Sequential coring, in-growth cores, minirhizotrons, Raich and Nadelhoffer (1989) approximation
Branches	Yes/No	Indicate whether branch production is included in the NPP estimate
Understory	Yes/No	Indicate whether understory production is included in the NPP estimate
Herbivory	Yes/No	Indicate whether herbivory loss is included in the NPP estimate
VOC	Yes/No	Indicate whether volatile organic compound loss is

		included in the NPP estimate
Reproductive parts	Yes/No	Indicate whether reproductive parts are included in the NPP estimate
Leaching	Yes/No	Indicate whether leaching from foliage and root exudation is included in the NPP estimate
Comments	Text	Essential comments to describe the methodology that was used to estimate NPP
Methodology class	Number	Method-specific reduction factor of total uncertainty of NP. See Table 1 above.
Source	Text	Website or publication where the NPP methodology is given

<2_Methodology_Rs_Rh_Ra.csv>		
Methodology number	Number	Unique number within this table, this number is used to describe the methodology in the level 3 tables
R_s	Text	Describe the method for measuring total soil respiration i.e., chambers, ground level eddy covariance or n.a. when not measured
R_s_method	Number	Method-specific reduction factor of total uncertainty of R_s. See Table 2 above.
R_h	Text	Describe the method for measuring heterotrophic respiration i.e., trenching, clear cuts, NPP-NEP, etc
R_h_method	Number	Method-specific reduction factor of total uncertainty of R_h. See Table 2 above.
R_a	Text	Describe the method for measuring autotrophic respiration
R_a_method	Number	Method-specific reduction factor of total uncertainty of R_a. See Table 2 above i.e., chamber, GPP-NPP, model (with name of model), etc.
Reference	Text	Website or publication where the R_s, R_h and/or R_a methodology is given

(3) Carbon Balance Component Estimates

<3_Estimate_GPP_NEP_Reco.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Begin year	Number	First year that GPP, NEP and/or Reco were estimated, 9999 when not known
End year	Number	Last year of the period that GPP, NEP and or Reco were estimated, use the year of publication when not known
NEP	Number	g C m^{-2} yr^{-1}
Reco	Number	g C m^{-2} yr^{-1}
GPP	Number	g C m^{-2} yr^{-1}
Methodology	Number	Number of the methodology according to table '2_Methodology_GPP_NEP_Reco'
Source	Text	Website or publication where GPP, NEP and/or Reco data are available

<3_Estimate_NPP.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Begin year	Number	First year that NPP was estimated, 9999 when not known
End year	Number	Last year of the period that NPP was estimated, use the year of publication when not known
NPP stem	Number	NPP of the stem in gC m^{-2} yr^{-1}
NPP foliage	Number	NPP of the foliage in gC m^{-2} yr^{-1}
ANPP_1	Number	Stem + foliage NPP
NPP branch	Number	NPP of the branches in gC m^{-2} yr^{-1}
NPP wood	Number	Stem + branch NPP
ANPP_2	Number	Foliage + wood NPP
NPP coarse	Number	NPP of the coarse roots in gC m^{-2} yr^{-1}
NPP fine	Number	NPP of the fine roots in gC m^{-2} yr^{-1}
BNPP_1	Number	Coarse + fine root NPP
TNPP_1	Number	Foliage + wood + coarse root + fine root NPP
NPP understory	Number	NPP of the understory in gC m^{-2} yr^{-1}
TNPP_2	Number	TNPP_1 + understory NPP
NPP repro	Number	NPP of the reproductive organs in gC m^{-2} yr^{-1}
TNPP_3	Number	TNPP_2 + reproductive parts NPP
NPP herbivory	Number	NPP of herbivory in gC m^{-2} yr^{-1}
TNPP_4	Number	TNPP_3 + herbivory NPP
NPP VOC	Number	NPP of VOC's in gC m^{-2} yr^{-1}
TNPP_5	Number	TNPP_4 + VOC NPP
NPP leaching	Number	NPP of leaching from foliage and root exudates in gC m^{-2} yr^{-1}

TNPP_6	Number	TNPP_5 + leaching NPP
Methodology	Number	Number of the methodology according to table '2_Methodology_NPP'
Source	Text	Website or publication where NPP data are available

<3_Estimate_Rs_Rh_Ra.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Begin year	Number	First year that R_s, R_h and/or R_a were estimated, 9999 when not known
End year	Number	Last year of the period that R_s, R_h and/or R_a were estimated, use the year of publication when not known
R_s	Number	Total soil respiration in gC m^{-2} a^{-1}
R_h	Number	Heterotrophic respiration in gC m^{-2} a^{-1}
R_a	Number	Autotrophic (belowground + aboveground) respiration in gC m^{-2} a^{-1}
Methodology	Number	Number of the methodology according to table '2_Methodology_Rs_Rh_Ra'
Reference	Text	Website or publication where R_s, R_h and/or R_a data are available

(4) Stand Data

<4_Site_labels.csv>		
Site ID	Auto Number	Unique number, assigned automatically
Site name	Text	Plot name according to table '1_Site_information'
Site label	Text	Unique 8 character label, the first 5 letters of the site name and 3 digits

<4_Stand_biomass_observed.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Begin year	Number	First year that the biomass was estimated, 9999 when not known
End year	Number	Last year of the period that the biomass was estimated, use the year of publication when not known
Foliar biomass	Number	Foliar biomass in gC m^{-2}
Branch biomass	Number	Branch biomass in gC m^{-2}
Stem biomass	Number	Stem biomass in g Cm^{-2}
Stump biomass	Number	Stump biomass in gC m^{-2}
Coarse root biomass	Number	Coarse root biomass in gC m^{-2}
Fine root biomass	Number	Fine root biomass in gC m^{-2}
Total aboveground	Number	Total aboveground biomass in gC m^{-2}

biomass		
Total belowground biomass	Number	Total belowground biomass in gC m^{-2}
Source	Text	Website or publication where the stand biomass data are available, please provide the complete bibliographic reference

<4_Stand_climate_observed.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Begin year	Number	First year that the climate was observed, 9999 when not known or when an unspecified long-term mean value
End year	Number	Last year of the period that the climate was observed, use the year of publication when not known or when an unspecified long-term mean value
Temperature	Number	Mean annual temperature in °C
Precipitation	Number	Total annual precipitation in mm
Evaporation	Number	Total annual evaporation in mm
APAR	Number	Total annual absorbed radiation in MJ m^{-2}
PAR	Number	Total annual incident radiation in MJ m^{-2}
Reference	Text	Website or publication where the climatic data are available

Notes for Stand Climate Observed Data. Sources of the data are as follows: APAR with reference JRC (2006) were calculated from 0.25° fapar and radiation data as APAR= FAPAR * PAR; assuming that PAR is 0.45 * global radiation. The FAPAR data were extracted from the EC-JRC database (JRC, 2006) and radiation data come from a regional climate model (Remo) that was driven with NCEP reanalysis (GKSS, 2001).

<4_Stand_description_observed.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Begin year	Number	First year that the stand was described, 9999 when not known
End year	Number	Last year of the period that the stand was described, use the year of publication when not known
Basal area	Number	Basal area in m^{-2} ha^{-1}
Diameter	Number	Diameter at breast height in m
Height	Number	Mean tree height in m
Density	Number	Stand density in number of trees ha^{-1}
Age	Number	Age of the dominant trees in years
Reference	Text	Website or publication where the stand description data are available

<4_Stand_leaf_area_index_observed.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Begin year	Number	First year that the stand was described, 9999 when not known
End year	Number	Last year of the period that the stand was described, use the year of publication when not known
LAI	Number	Maximal LAI between begin year and end year in $m^2 m^{-2}$
Projected	Text	Projected vs. total
Method	Text	Hemispherical photo, LI2000, litterfall, allometric relationship.
Source	Text	Website or publication where the stand biomass data are available, please provide the complete bibliographic reference

4_Stand_monthly_xxx_CRU and 4_Stand_monthly_xxx_ORCHIDEE		
<4_Stand_monthly_air_humidity_CRU.csv> <4_Stand_monthly_precipitation_CRU.csv> <4_Stand_monthly_temperature_CRU.csv> <4_Stand_monthly_wet_days_CRU.csv> <4_Stand_monthly_cloudcover_CRU.csv> <4_Stand_monthly_incoming_radiation_ORCHIDEE.csv> <4_Stand_monthly_net_solar_rad_ORCHIDEE.csv> <4_Stand_monthly_absor_down_long_rad_ORCHIDEE.csv> <4_Stand_monthly_net_surf_long_rad_ORCHIDEE.csv> <4_Stand_monthly_soil_moisture_ORCHIDEE.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Flag	Number	1 = values extracted from CRU or ORCHIDEE; 2 Values obtained from replacement site (see Table 3)
xxxx	Number	The columns in these files are named using the following naming convention: YYYYMM where, YYYY represents Year, MM represents Month.

Table 3. Site replacements for climate data

Data missing for	Data replaced by
Brookhaven	Morgan Monroe
Chamela 1	Luquillo
Chamela 2	Luquillo
Chamela 3	Luquillo
Cocoflux	Howards Spring
Kohala	Hawaii C
Kokee	Hawaii C
Michigan F3	Michigan C2
Mt Odaighara	Takayama

Mt Takoe	Takayama
Osa	La Selva
Puu Kolekole	Hawaii C
University of Michigan	Michigan C2

Note for Table 3: For sites located near large water bodies, the resolution of the CRU database was sometimes insufficient resulting in identifying the pixel as water. For those sites, the missing climatic data was replaced with the climatic data from the nearest site in the database.

4_Stand_NDVI_xxxx_xxxx_GMISS		
<4_Stand_NDVI_1982_1989_GMISS.csv> <4_Stand_NDVI_1990_1997_GMISS.csv> <4_Stand_NDVI_1998_2003_GMISS.csv>		
Plot	Text	Plot name according to table '1_Site_information'
NDVI	number	The columns in these files are named using the following naming convention: ndYYYYMMa where, YYYY represents Year, MM represents Month, a denotes the days 1-15 of the month, and b denotes the days from 16 to the end of the month. Example: nd198207a is the data for 1-15 of July, 1982, and nd198207b is the data for 16-31 of July, 1982.

Notes for NDVI Data: NDVI is the difference of near-infrared (channel 2) and visible (channel 1) reflectance values normalized over the sum of channels 1 and 2 (NIR-VIS)/(NIR+VIS). The NDVI equation produces values in the range of -1.0 to 1.0, where increasing positive values indicate increasing green vegetation and negative values indicate nonvegetated surface features such as water, barren, ice, snow, or clouds.

In the formulas below, the data, once imported, is referred to as the 'raw' data. To recover the -1 to 1 range of NDVI, use the following formula: NDVI = raw/10000; Example: If the value of a site is 6780, the value of NDVI of that site is: 6780*0.0001=0.6780

In the NDVI data, water pixels have a value of -10000 in the raw data, masked pixels are -5000, and missing pixels are -2000 plus the flag 6. The flag files can be retrieved from the NDVI data by the following formula: FLAG = raw - floor(raw/10) * 10; (where FLOOR(X) rounds the elements of X to the nearest integers towards minus infinity.)

The meaning of the FLAG:
FLAG = 6 (missing data)
FLAG = 5 (NDVI retrieved from average seasonal profile, possibly snow)
FLAG = 4 (NDVI retrieved from average seasonal profile)
FLAG = 3 (NDVI retrieved from spline interpolation, possibly snow)
FLAG = 2 (NDVI retrieved from spline interpolation)
FLAG = 1 (Good value, possibly snow)

FLAG = 0 (Good value)

4_Stand_ monthly_xxxx_ORCHIDEE		
<4_Stand_monthly_net_solar_radiation_ORCHIDEE.csv> <4_Stand_monthly_net_surface_long_radiation_ORCHIDEE.csv> <4_Stand_monthly_absor_down_long_radiation_ORCHIDEE.csv> <4_Stand_monthly_soil_moisture_ORCHIDEE.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Variable	Number	The columns in these files are named using the following naming convention: YYYYMM where, YYYY represents Year and MM represents Month

Notes for ORCHIDEE Meteorological Data: The data are derived from the ORCHIDEE model (Krinner et al., 2005) for the period 1990-2003. The variable depends on this table. The following variables have separate tables: net solar radiation (W m^{-2}), net surface longwave radiation (W m^{-2}), absorbed downwards longwave radiation (W m^{-2}), and soil moisture (mm).

4_Stand_xx_deposition_ORCHIDEE		
<4_Stand_N_dry_deposition_ORCHIDEE.csv> <4_Stand_N_wet_deposition_ORCHIDEE.csv> <4_Stand_NHx_deposition_ORCHIDEE.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Variable	Number	The columns in these files are named using the following naming convention: MM where, MM represents Month

Notes for ORCHIDEE Deposition Data: The data are derived from the ORCHIDEE model (Krinner et al., 2005) for the period 1990-2003. The variable depends on this table. The following variables have separate tables: dry N deposition (gN/m^2/mth), wet N deposition (gN/m^2/mth) and Ammonia deposition (gN/m^2/mth) derived from the emission field.

<4_Stand_N_deposition_1993_GALLOWAY.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Flag for wet deposition	Number	1: observed deposition (modeled EMEP, NADP or NDDN) 3: corrected modeled deposition
Wet deposition	Number	Deposition value in gC m^{-2} yr^{-1}
Flag for dry deposition	Number	1: observed deposition (modeled EMEP, NADP or NDDN) 2: corrected observed deposition 3: corrected modeled deposition
Dry deposition	Number	Deposition value in gC m^{-2} yr^{-1}

Flag for total deposition	Number	1: observed deposition (modeled EMEP, NADP or NDDN) 2: corrected observed deposition 3: corrected modeled deposition
Total deposition	Number	Deposition value in gC m^{-2} yr^{-1}

Notes for Galloway Deposition Data: Interpolated gridded maps based on ground observations (EMEP, NADP and NDDN) of several N-species are available for Western Europe and the conterminous U.S.A. (Holland et al., 2004). Total wet deposition for the U.S.A. and Europe was computed as the sum of aqueous NO_3^- and NH_4^+ fields. Total N deposition for Western Europe was computed as the sum of wet and dry deposition where dry deposition was the sum of NO_2, NH_4^+, HNO_3 and NO_3^-. However, only the sum of nitric acid and particulate nitrate was measured (Holland et al., 2005); therefore, their relative fields represent end-members assuming only one N-species. In our calculation of the dry deposition we took the average value of nitric acid and particulate nitrate. Additional data for 1993 for the rest of the globe were derived from model simulations (Galloway et al., 2004; Dentener, 2006); estimates of wet N deposition were then derived from modelled values of total N deposition, based on a correlation (see Magnani et al., 2007) between measured total and wet deposition values from Western Europe.

<4_Stand_soil_composition_IGBP_DIS.csv>		
Plot	Text	Plot name according to table '1_Site_information'
Sand	Number	Volume % of sand
Silt	Number	Volume % of silt
Clay	Number	Volume % of clay

Notes for Stand Soil Composition Data: The source is IGBP_DIS Global Soil Data Task Group (2000). The spatial resolution is 5 minutes. Mass percentages were converted to volumetric percentages by dividing the mass percentage by the bulk density (i.e., 1.19 g/cm^3 for sand and 0.94 g/cm^3 for clay. The percentage silt was calculated as the difference of the volumetric percentage sand and clay from 100%.

Exported View Data (Queries) From the Database (.csv format) -- The view data files (generated from queries of the database) are derived from the data tables and contain useful information. All of the view data have been exported, so that there is an Excel csv format file for each view containing all of the data that are derived from a particular query. They show summary data for sites (e.g., a C-flux for GPP, NEP, Reco, NPP, R_a, R_h or R_s). The view data files are compressed and provided in one file <forest_carbon_flux_views.zip>. The documentation file <Documentation_literature_compilation_v3.1.pdf> describes how the views are constructed and what is in them.

- Please be advised that some of the exported views are structured by plot (site) and link by the field 'Plot name' to the <1_Site_information.csv> table. Note that this field in the view tables is named either 'Plot' or 'Plot name'.

0_Individual_xxx_number of years
<0_Individual_GPP_NEP_Reco_number_of_years.csv> <0_Individual_NPP_components_number_of_years.csv> <0_Individual_Rs_Rh_Ra_number_of_years.csv>
These view data are derived from the query that calculates the number of years during which a single observation/entry was measured.

1_Individual_xxx_with uncertainty
<1_Individual_GPP_NEP_Reco_with_uncertainty.csv> <1_Individual_NPP_components_with_uncertainty.csv> <1_Individual_Rs_Rh_Ra_with_uncertainty.csv>
These view data are derived from the query that calculates the variability accounting for length of the observation and the method that was used to measure the C-flux. The uncertainty is used in higher level queries.

Table 4. Variability (gC m^{-2} yr^{-1}) of a component flux determined by expert judgment and assuming the absence of measurements

Component flux	Prior	Variability
GPP	Latitude	500 + 7.1 * (70 – Latitude)
NPP	Latitude	350 + 2.9 * (70 – Latitude)
NEP	-	350 if Latitude > 23 700 if Latitude < 23
R_e	Latitude	500 + 7.1 * (70 – Latitude)
R_s	Latitude	200 + 8.6 * (70 – Latitude)
R_h	Latitude	100 + 2.9 * (70 – Latitude)
R_a	Latitude	100 + 4.3 * (70 – Latitude)
For more details, see Luyssaert et al. (2007).		

<1_Individual_Stand_description.csv>
These view data are derived from the query that calculates year of stand establishment. The year of establishment can be used to calculate the age of the forest at the time that the C-flux was measured in higher-level queries.

2_Intermediate_xxxx_sum_of_weights_per_year
<2_Intermediate_GPP_NEP_Reco_sum_of_weights_per_year_weights.csv> <2_Intermediate_NPP_components_sum_of_weights_per_year.csv> <2_Intermediate_Rs_Rh_Ra_sum_of_weights_per_year.csv>
These view data are derived from the query that calculates intermediate results at the site and year level that are used in the higher-level queries.

3_Intermediate_xxx_per_year
<3_Intermediate_GPP_NEP_Reco_per_year.csv> <3_Intermediate_NPP_components_per_year.csv> <3_Intermediate_Rs_Rh_Ra_per_year.csv>
These view data are derived from the query that calculates the weighted mean for the C-flux and the weighted std at the site and year level.

4_Intermediate_xxx_sum_of_weights_per_site
<4_Intermediate_GPP_NEP_Reco_sum_of_weights_per_site.csv> <4_Intermediate_NPP_components_sum_of_weights_per_site.csv> <4_Intermediate_Rs_Rh_Ra_sum_of_weights_per_site.csv>
These view data are derived from the query that calculates the intermediate results at the site level.

5_Grouped_xxx_with_uncertainty
<5_Grouped_GPP_NEP_Reco_with_uncertainty.csv> <5_Grouped_NPP_components_with_uncertainty.csv> <5_Grouped_Rs_Rh_Ra_with_uncertainty.csv>
These view data are derived from the query that calculates the uncertainty for the weighted mean for the C-flux at the site level.

Methods and Methods

Theory:

Terrestrial ecosystems sequester 2.1 Pg of atmospheric carbon annually. A large amount of the terrestrial sink is realized by forests. However, considerable uncertainties remain regarding the fate of this carbon over both short and long timescales. Relevant data to address these uncertainties are being collected at many sites around the world, but syntheses of these data are still sparse. This database was assembled to facilitate future synthesis activities.

Data Collection:

The CO_2 balances for boreal, temperate, and tropical forest biomes are based on micrometeorological, ecophysiological, and biometric flux and inventory estimates. The methods used to assemble this database are described in Luyssaert et al. (2007) and are summarized herein. Also see Aubinet et al. (2000), Clark et al. (2001), and Hanson et al. (2000) for methodological approaches to estimating carbon exchange in forests.

Database

A comprehensive relational database structure was designed to store information on carbon fluxes, ecosystem properties, and site information of forest stands.

Data entries originated from peer-reviewed literature, established databases (e.g. Olson et al., 2001; Papale et al., 2006) and personal communications with research groups involved in the FLUXNET project (Baldocchi et al., 2001) and the various regional flux networks (Afriflux, AmeriFlux, AsiaFlux, CarboAfrica, CarboEurope-IP, ChinaFlux, Fluxnet-Canada, KoFlux, LBA, NECC, OzFlux, TCOS-Siberia, USCCC). See Appendix A for a list of published and unpublished data sources and contact information for data contributors.

The high quality of the database is ensured by several features: (1) referential integrity is ensured by the structure of the database; (2) data selection is based on strict methodological criteria; (3) consistency of the NPP data is ensured by a hierarchical framework; (4) uncertainty of the fluxes are estimated in a consistent manner accounting for the methodological approach and the length of the time series; (5) the uncertainty of aggregated fluxes is estimated; and (6) a variety of observed and/or modeled metadata are included in the database.

Structure of the database. The database is structured by site. A site is a forest or a stand with a known geographical location, biome (U.S. Department of Agriculture biome classification; Reich & Eswaran, 2002), tree species composition, and management regime (Table 5). Each site in the database is linked to at least one carbon balance component and each component is further linked to the methodology that was used to estimate it. Data from different sources or references are stored as different entries to ensure referential integrity of the database.

Table 5. Overview of the Information Contained in the Database

Plot Information		
Plot name	Text	Name of the plot
Biome	Text	Biome according to U.S. Department of Agriculture (1999)
Growth strategy	Text	Evergreen, deciduous or mixed
Growth form	Text	Needle-leaved, broadleaved or mixed
Tree species	Text	Dominant tree species
Tree species	Text	Co-dominant tree species
Latitude	Number	Latitude in decimal degrees
Longitude	Number	Longitude in decimal degrees
Elevation	Number	Elevation above sea level in m
Management	Text	Relevant information on management and disturbance

Observed Stand Characteristics		
Basal area	Number	Basal area in m^{-2} ha^{-1}
Diameter	Number	Diameter at breast height in m
Height	Number	Mean tree height in m
Density	Number	Stand density in number of trees ha^{-1}
Age	Number	Age of the dominant trees in years

LAI	Number	Maximal LAI in $m^2 m^{-2}$
Method	Text	Description of the method used to determine LAI

Observed Stand Biomass		
Foliar biomass	Number	Foliar biomass in gC m^{-2}
Branch biomass	Number	Branch biomass in gC m^{-2}
Stem biomass	Number	Stem biomass in gC m^{-2}
Stump biomass	Number	Stump biomass in gC m^{-2}
Coarse root biomass	Number	Coarse root biomass in gC m^{-2}
Fine root biomass	Number	Fine root biomass in gC m^{-2}
Aboveground biomass	Number	Total aboveground biomass in gC m^{-2}
Belowground biomass	Number	Total belowground biomass in gC m^{-2}

Observed Stand Climate		
Temperature	Number	Mean annual temperature in °C
Precipitation	Number	Total annual precipitation in mm
Evaporation	Number	Total annual evaporation in mm
APAR	Number	Total annual absorbed radiation in MJ m^{-2}
PAR	Number	Total annual incident radiation in MJ m^{-2}
IPAR	Number	Total annual intercepted radiation in MJ m^{-2}

Observed Flux Estimate		
GPP	Number	Ecosystem GPP in gC m^{-2} yr^{-1}
NEP	Number	Ecosystem NEP in gC m^{-2} yr^{-1}
R_e	Number	Ecosystem Re in gC m^{-2} yr^{-1}
NPP wood	Number	NPP of the stems/wood in gC m^{-2} yr^{-1}
NPP foliage	Number	NPP of the foliage in gC m^{-2} yr^{-1}
NPP branch	Number	NPP of the branches in gC m^{-2} yr^{-1}
NPP stumps	Number	NPP of the stumps in gC m^{-2} yr^{-1}
NPP coarse	Number	NPP of the coarse roots in gC m^{-2} yr^{-1}
NPP fine	Number	NPP of the fine roots in gC m^{-2} yr^{-1}
NPP repro	Number	NPP of the reproductive organs in gC m^{-2} yr^{-1}
NPP herbi	Number	NPP of the herbivory in gC m^{-2} yr^{-1}
NPP under	Number	NPP of the understory in gC m^{-2} yr^{-1}
NPP VOC	Number	NPP of the VOC's in gC m^{-2} yr^{-1}
NPP exudates	Number	NPP of the root exudates in gC m^{-2} yr^{-1}
R_s	Number	Total soil respiration in gC m^{-2} yr^{-1}
R_a	Number	Autotrophic respiration in gC m^{-2} yr^{-1}
R_h	Number	Heterotrophic respiration in gC m^{-2} yr^{-1}
Methodology	Text	Description of the different

		methodologies that were used to estimate the fluxes

Site Climate and Environment		
Temperature	Number	Monthly mean annual temperature in °C from CRU data set (2006) (Mitchell and Jones, 2005)
Precipitation	Number	Monthly precipitation sum in mm from CRU data set (2006) (Mitchell and Jones, 2005)
Air humidity	Number	Monthly air humidity (%) from CRU data set (2006) (Mitchell and Jones, 2005)
Cloud cover	Number	Monthly average cloud cover (%) from CRU data set (2006) (Mitchell and Jones, 2005)
Number of wet days	Number	Monthly sum of wet days from CRU data set (2006) (Mitchell and Jones, 2005)
Long wave radiation (1)	Number	Monthly absorbed downward longwave radiation in W m^{-2} from ORCHIDEE model (Krinner et al., 2005)
Long wave radiation (2)	Number	Monthly net surface longwave radiation in W m^{-2} from ORCHIDEE model (Krinner et al., 2005)
Solar radiation	Number	Monthly solar radiation in W m^{-2} from ORCHIDEE model (Krinner et al., 2005)
Soil moisture	Number	Monthly soil moisture in mm from ORCHIDEE model (Krinner et al., 2005)
Dry deposition	Number	Mean monthly dry deposition of NgN m^{-2} $month^{-1}$ from ORCHIDEE model (Krinner et al., 2005)
Wet deposition	Number	Mean monthly wet deposition of NgN m^{-2} $month^{-1}$ from ORCHIDEE model (Krinner et al., 2005)
NH*x* deposition	Number	Mean monthly NH*x* deposition of NgN m^{-2} $month^{-1}$ from ORCHIDEE model (Krinner et al., 2005)
NDVI	Number	Mean 14-day NDVI (Tucker et al., 2005)

In total, 528 forest sites (plots) are included in the database. See Luyssaert et al. (2007) for a discussion of site and biome representation in the database. Note: the database has been updated to add additional sites since the publication of Luyssaert et al. (2007). See Version Information in <Documentation_literature_compilation_v3.1.pdf> (this archive).

Data selection criteria. Flux estimates were included in the database when they were based on direct measurements (NPP, NEP, R_s, R_h, and R_a), derived from single or multiple direct measurements (GPP, NPP, NEP, R_e, R_h, and R_h), or modeled (GPP, NPP, NEP, R_s, R_h, and R_a). See Luyssaert et al. (2007) for methodological details.

Data consistency/uncertainty. Luyssaert et al. (2007) describe how they dealt with consistency of the flux data, uncertainty of the measured CO_2 fluxes, and aggregated fluxes and their uncertainty.

Site description data. Additional site information related to stand characteristics, standing biomass, leaf area index, and growing environment was added to the database as separate tables. Stand characteristics such as basal area, mean tree diameter, mean tree height, mean tree density, and mean stand age are available for many sites. Also, the observed standing biomass and its major components, the maximal observed leaf area index, and some methodological details of the leaf area measurement technique are available for many sites. For almost all of the sites, soil texture (expressed as the volumetric percentage of sand, silt and clay) was extracted from Global Soil Data Products CD-ROM (IGBP-DIS) (Global Soil Data Task Group, 2000) at 5-minute spatial resolution. The growing environment was characterized by the observed mean annual temperature and annual precipitation. Finally, a description of stand management was also included in the database. See Luyssaert et al. (2007) for more information about the sites.

Biome-specific CO_2 balances. The different biomes were characterized by way of stand and climate descriptions. The stand description was based on observed values and the climate description was based on the CRU data set (Mitchell and Jones, 2005) and ORCHIDEE model output (Krinner et al., 2005). All data were extracted from the database and mean values with their SD were presented for the different biomes. Uncertainty for each carbon balance component was estimated in a uniformed way by expert judgment. Robustness of the CO_2 balances was tested, and closure terms were introduced as a numerical way to approach data quality and flux uncertainty at the biome level. See Luyssaert et al. (2007) for details.

Spatial Coverage:

Global (although southern hemisphere ecosystems are highly underrepresented with just 21 sites) (Figure 1)

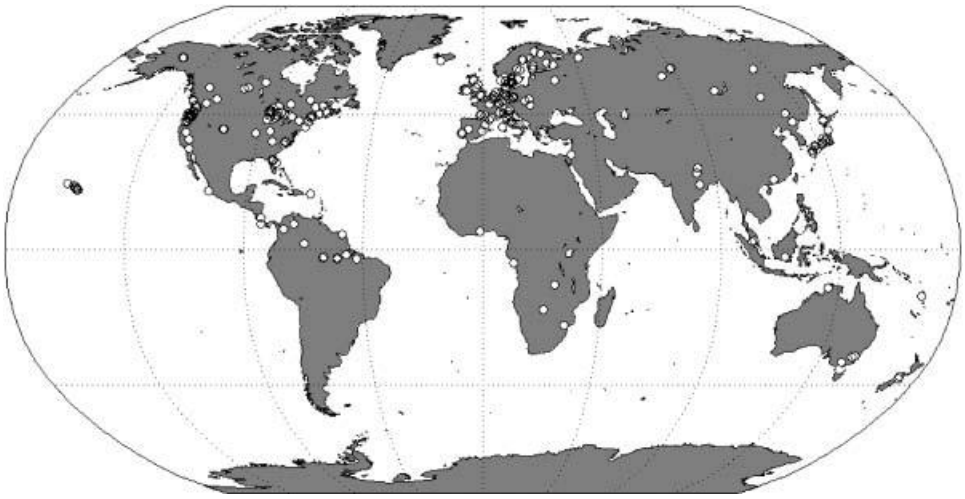

Figure 1. Geographical Distribution of the Sites Contained in the Database

Spatial Resolution:

For low-resolution model comparison, the data are aggregated by latitudinal and longitudinal grid cells. For analyzing carbon balances of different forests, the data are aggregated by site. For analyzing carbon balances of different biomes, site-specific data are extracted from the database and aggregated for the different biomes. The biome-specific flux values are representative for the sites contained in the database and not necessarily representative of the entire biome.

Temporal Coverage:

The database contains data collected between 1897 and 2006.

Temporal Resolution:

Annual

Data Usage Guidance

Limitations of the Data:

Southern hemisphere ecosystems ware highly underrepresented, with just 21 sites. Many common tree species from the southern hemisphere are, therefore, not represented in the database and coverage would greatly benefit from additional southern hemisphere data. However, only part of the data that is collected within the framework of FLUXNET was available for use at the time this synthesis was conducted. The database will be updated as additional data become available.

All main climatic regions that support forest growth are present in the database. However, temperate humid forests are overrepresented in their areal extent, there is a

lack of data for Mediterranean cold forests, and semiarid forests, (particularly in the tropics) appear to be under-studied.

The flux values in the CO_2 balances should be interpreted as the most reliable mean estimates currently available. However, it should be noted that the balances are only representative for a larger region as far as the sites with the long time series and more precise flux estimates are representative for that region. As with most general patterns, these mean fluxes, which are the result of both spatial and temporal averaging, may not apply to specific sites or specific years.

Known Problems with the Data:

Despite the strict data selection criteria, there are still inconsistencies between methodological approaches to estimate carbon flux. Additionally, there are uncertainties for the measured component fluxes as well as uncertainties for the aggregated fluxes. Luyssaert et al. (2007) explain how the inconsistencies and uncertainties were dealt with in this database.

Quality Assessment Activities:

Robustness of the CO_2 balances was tested, and closure terms were introduced as a numerical way to approach data quality and flux uncertainty at the biome level. In all biomes, closing the CO_2 balance required the introduction of substantial biome-specific closure terms. Luyssaert et al. (2007) explain data consistency and quality control mechanisms.

Additional Sources of Information

For additional information about this database, please see the documentation file <Documentation_literature_compilation_v3.1.pdf> which contains the fair use policy for this database, data base version (change) information, data table and query documentation, documentation references, published and unpublished database sources, and names and addresses of data contributors.

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