Carbon dynamics of mature and regrowth tropical forests derived from a pantropical database (TropForC-db)

Anderson-Teixeira, K.J. et al., *Global Change Biology* (2016) 22, 1690-1709
doi: 10.1111/gbc.13226

Objectives:

- Tropical forests play a critical role in the global carbon (C) cycle, storing about 45 percent of terrestrial carbon and constituting the largest component of the terrestrial carbon sink.
- Despite the importance of tropical forests, gaps in the knowledge of their ecosystem-level carbon cycle hampers efforts to quantify carbon budgets across the tropics and to model tropical forest-climate interactions.
- In this study, the authors compile and present a new database on carbon dynamics of tropical forests, the Tropical Forest C database (Trop-ForC-db) and use it to synthesize current knowledge about tropical forest carbon dynamics and to identify key uncertainties.
- The authors compiled the database from existing data compilations and data drawn from original studies that were identified using an extensive literature search.
- The database contains 3,568 records from 845 plots in 178 geographically distinct areas, making it the largest and most comprehensive database of its type.
- The TropForC-db consists of a series of cross-referenced data tables describing sites, plots and their history, measurements of C cycle variables, disturbance/history event type, plant functional types and species, methodologies, and allometries.
- In this study, the authors used TropForC-db to characterize C stocks and annual fluxes for young, intermediate-aged, and mature/intact forests, comparing the latter to existing budgets for extra-tropical forests, examined budgets for extra-tropical forests, and examined patterns of C accumulation following stand-clearing disturbance.
- Complete definitions of all variables and equations relating to the variables are included in the data files and complete metadata is given in an associated data publication in Dryad Digital Repository (http://dx.doi.org/10.5061/dryad.t516f).

New Science:

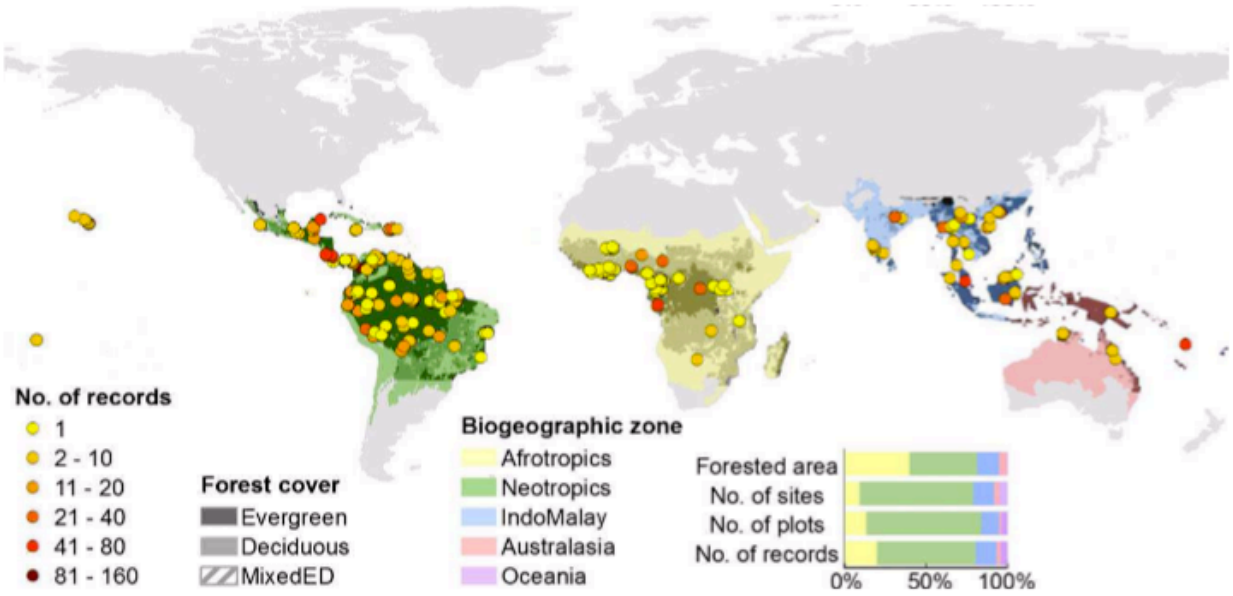
- The study found that, relative to existing C budgets of extra-tropical forests, mature tropical broadleaf evergreen forests had substantially higher gross primary productivity (GPP) and ecosystem respiration (R_{eco}) while the autotropic respiration (Ra) consumed a larger proportion (~67%) of GPP.
- It was also found that woody stem growth ($ANPP_{stem}$) represented a smaller proportion of net primary productivity (NPP~32%) or GPP (~9%) relative to extra-tropical forests.
- In regrowth stands, aboveground biomass increased rapidly during the first 20 years following stand-clearing disturbance, with slower accumulation following agriculture and in deciduous forests, and continued to accumulate at a slower pace in forests aged 20-100 years.
- Most other C stocks also increased with stand age, while the capacity to describe age trends in C fluxes was generally data-limited.
- Aboveground biomass, total root biomass, and total biomass all accumulated as forests aged, and on average were highest in mature forest stands, with at least marginally significant differences in all pairwise comparisons among young, intermediate and mature age classes.
- The ensemble C budget of mature, unmanaged, broadleaf evergreen forests differs from those of extra-tropical forests in three important ways: gross C fluxes into and out of the ecosystem (GPP and R_{eco}) are

much larger than in extra tropical forests; the ratio of NPP to GPP (or carbon use efficiency) is lower than average values observed for other forest biomes globally; and the proportion of NPP allocated to stem productivity ($ANPP_{stem}$) as opposed to root or leaf productivity (BNPP and $ANPP_{foliage}$) is lower in the tropics than in other forest biomes.

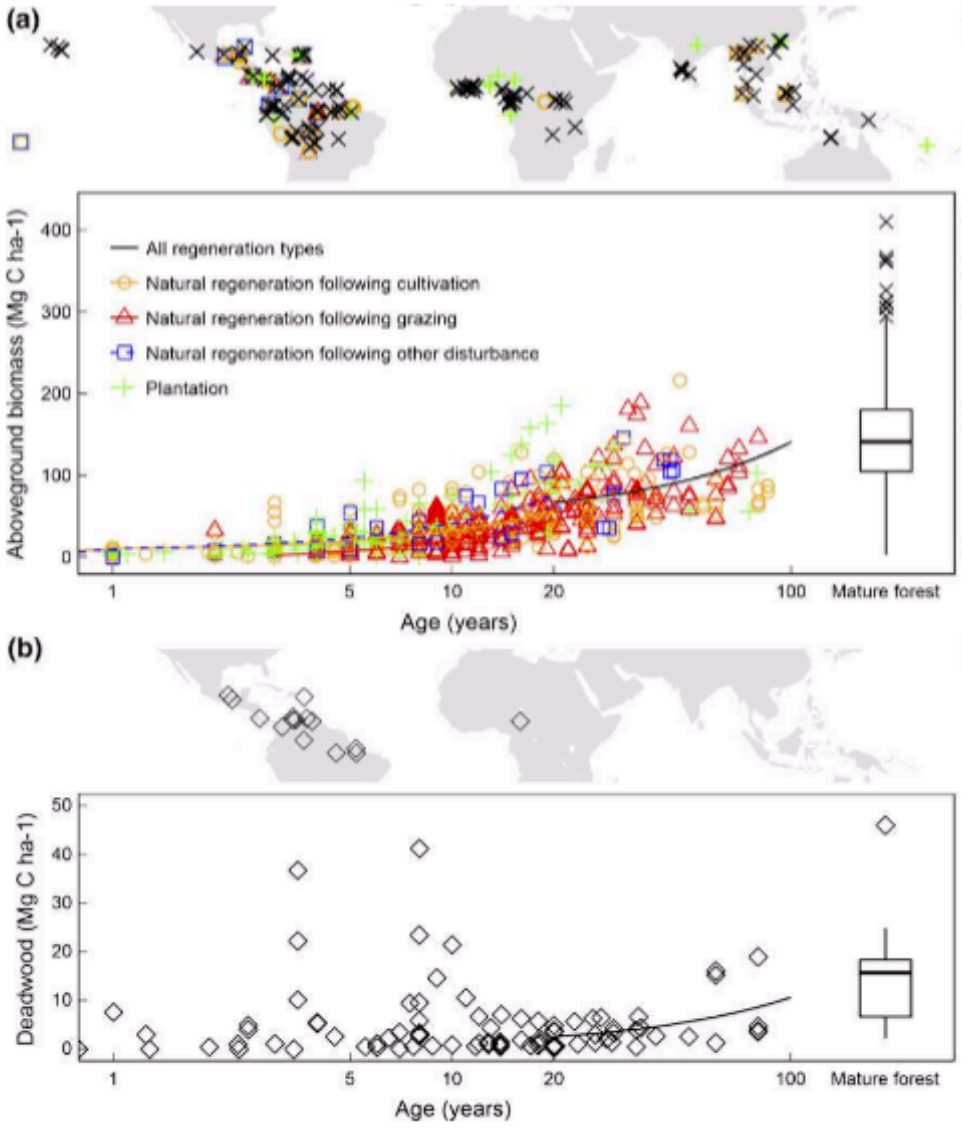
- The ensemble estimates of C fluxes in mature, unmanaged, broadleaf evergreen forests presented in this study are generally consistent with previous work characterizing tropical forest C budgets, with modest differences in GPP and net ecosystem productivity.

Significance:

- The authors anticipate that TropForC-db will be valuable for various initiatives, especially for synthetic analysis that attempts to better understand tropical forest C stocks and fluxes, how these are shaped by past disturbance, and how these are influenced by environmental factors, as well as for model calibration, benchmarking, and improvement.
- The findings in this analysis yield insights into the relative influence of various factors on aboveground biomass accumulation rate, which is a critical factor in accurately characterizing the role of tropical regrowth forests in the global C cycle.
- Important limitations of the body of data used in compiling this database include data coverage, standardization and uncertainty.
- Several measurements, including NPP and ecosystem-atmosphere CO_2 exchange (NEE, GPP, and R_{eco}) are particularly challenging in tropical forests, which are highly underrepresented in terms of eddy flux measurements; C flux variables are also particularly sparse in regrowth forests.
- Aboveground biomass is the variable with the most available records; however, coverage remains sparse for many parts of the tropics.
- Future research aimed at filling in data gaps, especially in eddy flux measurements (CO_2) and C flux variables will be of great value.
- It is important to bear in mind that the ensemble C budget is unlikely to be completely accurate for any given stand; rather, there is substantial variation around these means.
- The database represents a substantive effort to assemble existing data on tropical forest C stocks and fluxes; it is by no means complete in terms of including all available and relevant data.
- The authors anticipate ongoing development of the TropForC-db database and a dynamic instance of the database will be accessible on line at https://github.com/for-db.
- Future studies that draw upon TropForC-db are encouraged to seek out additional available data for the variables or forest types of interest and contribute these data to the database.



Geographical distributions of sites included in TropForC-db. Map shows satellite-derived coverage of evergreen and deciduous forest (from SYNMAP; Jung et al., 2006). Inset shows distributions of sites, plots, and records among biogeographic regions (sensu Olson et al., 2001).



Age trends in (a) aboveground biomass and (b) dead wood for forest regeneration following stand-clearing disturbances. Maps show the sites from which data were obtained. Forests are grouped by young, intermediate-aged, and mature/intact, showing separate statistical fits for each age class. Regression lines indicate mixed model where age and regeneration type (aboveground biomass in young stands only) are fixed effects and plot nested within area is a random effect.