Informing IPCC accounting of forest carbon using the global forest carbon database (ForC v4.0)

Madison Williams[1], Valentine Herrmann[1], Rebecca Banbury Morgan[1,2], Ben Bond-Lamberty[3], Susan Cook-Patton[4], Sandro Federici[5], Helene Muller-Landau[6], Camille Piponiot[7], Teagan Rogers[1], Valentyna Slivinska[5], and Kristina J. Anderson-Teixeira[1,6] *

[1]Center for Conservatiton Ecology, Smithsonian Conservation Biology Institute, Front Royal, VA, United States
[2]School of Geography, University of Leeds, Leeds, UK
[3]Joint Global Change Research Institute, Pacific Northwest National Laboratory, College Park, MD, United States
[4]The Nature Conservancy; Arlington VA 22203, USA
[5]IPCC Task Force on National Greenhouse Gas Inventories Technical Support Unit, Institute for Global Environmental Strategies, Hayama, Japan
[6]Forest Global Earth Observatory, Smithsonian Tropical Research Institute, Panama, Republic of Panama
[7]CIRAD, Montpellier, France

Correspondence: Kristina J. Anderson-Teixeira (teixeirak@si.edu)

Abstract. The abstract goes here. It can also be on *multiple lines*.

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1 Introduction

As we seek to mitigate climate change (UNFCCC, 2015), forests are critical. *(See intros to other papers for relevant refs)* Under Paris Agreement, ##% of Nationally Determined Contributions relate to forests (Grassi et al., 2017).

The International Panel on Climate Change (IPCC) provides guidance for national greenhouse gas (GHG) inventories for reporting to the United Nations Framework Convention on Climate Change (UNFCCC, (REFS for older guidelines), IPCC, 2019a). Under this guidance, GHG inventories are to include all managed land, including most of the world's forest land (Ogle, 2018). The IPCC inventory guidelines include specific instructions for accounting for forest land ... (IPCC, 2006, 2019b). This guidance has improved as more of the relevant underlying data has become available (Requena Suarez et al., 2019), but there remains room for continuous improvement as the science advances. For example, Cook-Patton et al. (2020) *(summarize IPCC comparison results). Moreover, it is useful for those compiling national greenhouse gas inventories to have access to locally-specific information, when available.* To improve the data accessible for C accounting, the IPCC created the Emission Factor Database (EFDB; https://www.ipcc-nggip.iges.or.jp/EFDB/main.php), which is intended as a recognized library of emission factors and other parameters that can be used for estimating greenhouse gas emissions and removals.

The Global Forest Carbon Database, ForC, is the largest collection of published estimates of forest carbon stocks, increments, and annual fluxes (Anderson-Teixeira et al., 2018, 2021). *(add stats/ details)* As such, ForC is positioned to improve forest C accounting through the transfer of data to EFDB. The purpose of this publication is to document that process and provide recommendations for future improvements.

Here, we (1) clarify definitions of relevant carbon stocks and increments (2) describe mapping of ForC to IPCC's EFDB, (3) describe updates to ForC (ForC v4.0), (4) summarize the data in ForC that's relevant to EFDB, identifying gaps, and (5) provide recommendations for improving data collection, analysis, database, and accounting.

2 Defining carbon stocks and incremenets

For quantifying forest role in global C cycle, we ultimately care about: (1) C stocks – stores of C that would be vulnerable to release to the atmosphere upon land use change (2) C increments – changes in those C stocks.

2.1 Carbon stocks

Forest ecosystem C stocks may be parsed into pools in various ways. IPCC parses into biomass (aboveground and below-ground), dead organic matter (dead wood and litter), and soil organic matter (Table 1). Quantifying these requires a one-time measurement.

pool	pool	definition	major sources of estimate variation	IPCC guidance
biomass	aboveground	all biomass of living vegetation, both woody and herbaceous, above the soil	allometry, min dbh	acceptable to exclude understory
	belowground	all biomass of live roots	allometry, min dbh, assumed ratio of belowground to aboveground biomass (IPCC table 4.4)	fine roots may be excluded when they cannot be distinguished empirically from soil organic matter or litter
dead organic matter	dead wood	all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil	min dbh, . . .	default min dbh = 10cm, but may be chosen by country
	litter	all non-living biomass with a size greater than the limit for soil organic matter and less than the minimum diameter chosen for dead wood, lying dead, in various states of decomposition above or within the mineral or organic soil	min dbh for dead wood , ..	
soils	soil organic matter	organic carbon in mineral soils to a specified depth	sampling depth	default sampling depth = 30cm, but may be chosen by country

Figure 1. Table 1

Table 1. This is a start at table 1 using the template format.

pool	subpool	definition	major sources of estimate variation	
biomass	aboveground	all biomass of living vegetation, both woody and herbaceous, above the soil	allometry, min dbh	accept

I don't know how to adjust so that it doesn't run off the page.

Table 1: variables with definitions and measurement methods. Definitions from IPCC Table 1.1. (See Table 1.1 in IPCC guidance). (*Currently adding this as a figure (generated from original draft) because kableExtra doesn't seem to work in this template, and I can't quickly get the template format to work. Table that we want here is "figures_tables/C_pools.csv"*)

2.2 Carbon increments

C increments are defined as the change over time, in annual increments, in each C pool. These may be estimated as the difference between C stocks at two time points, or as the difference between inputs and outputs to the pool (i.e., fluxes). Quantifying these requires at least two measurements.

Fluxes are the inputs and outputs to each pool.

Figure: schematic illustrating fluxes in and out of each pool

3 Mapping ForC to EFDB

3.1 Carbon cycle variables

Table: variable mapping and equations– give equations to calculate IPCC variables from C cycle variables

Define relationship among NEE, NEP, and delta.C., especially noting role of harvest.

3.2 Land use categories

Documented at https://github.com/forc-db/IPCC-EFDB-integration/blob/main/doc/ForC-EFDB_mapping/defining_land_subcategory.md, https://github.com/forc-db/IPCC-EFDB-integration/blob/main/doc/ForC-EFDB_mapping/IPCC_LandUse_mapping.csv, and in issue #8.

The UNFCCC requires GHG reporting for all managed lands in a country, where management is defined as "human interventions and practices have been applied to perform production, ecological or social functions" [*IPCC 2006 full report REF*]. This definition is applied differently across countries, and is not clearly defined by the majority of governments (Ogle, 2018). Given this, and because the IPCC definition of management does not necessarily match that which would be reported in scientific publications and hence in ForC, we do not transfer any classification of land management status from ForC to the EFDB, but do provide auxiliary info that may be useful in making this determination (e.g., geographical location).

4 Updates to ForC (ForC v4.0)

To support export of data to EFDB, and to improve the overall quality of the ForC database, we implemented some modest restructuring, resolved duplicate records, and conducted quality control. This section describes changes relative to ForC v2.0 (Anderson-Teixeira et al., 2018).

4.1 ForC restructuring

Table	Column	Description	Changes
Sites	coordinates.precision	Precision of geographic coordinates, as reported by source or estimated from maps.	field added
Measuremennts	data.location.within.source	Location of data within the source listed in citation.ID.	field added
	sd, se, lower95%CI, upper 95%CI	Standard deviation, standard error, and lower and upper 95 percent confidence intvervals, respectively.	replaces `stat` a
	mean.in.original.units, original.units	mean value and units presented in original publication	fields added
	C.conversion.factor	Assumed/ measured C content of organic matter used to convert organic matter to C.	field added
PFT	description	Definition of the pftcode at the community level. Differs from individual level in that properly describes mixed plant functional types.	field added
	description.individual	Definition of the pftcode at the individual plant level.	field name chan
Citations	(several fields)		

Figure 2. Table of changes to ForC fields (placeholder)

(The above is a placeholder for the table located at https://github.com/forc-db/ForC/blob/master/database_management_records/record_of which we'll need to format.)

4.2 Quality control measures

Prior to releasing ForC v4.0, we executed several quality control measures. First, to improve information on geographic coordinates, we flagged and reviewed records with suspected low precision *(Issue #29)[https://github.com/forc-db/ForC/issues/229]*. Second, to identify erroneous climate data… *(Issue #212)[https://github.com/forc-db/ForC/issues/212]*.

4.3 Resolving duplicates

5 Results

figure: map of relevant ForC data with underlying FAO ecozones

(summarize the data in ForC that's relevant to EFDB, identifying gaps)

dead wood and litter comparisons will be particularly interesting, as IPCC values are based on just a handful of references for each climate zone (table 2.2 in 2019 guidelines)

6 Recommendations

6.1 Data collection and analysis needs

(Paragraph highlighting important gaps in variables / regions)

Several variables of value to IPCC, including standing dead wood, woody mortality, delta.agb, are not calculated and presented as frequently as are AGB and ANPP_woody, even though they can readily be derived from the same census data. We recommend that researchers calculate and report these, as specified below. Furthermore, there is an opportunity to fill data gaps by calculating these from existing census data. For example, the core census protocol of the Forest Global Earth Observatory [ForestGEO; REFS] collects the data required to calculate standing dead wood, woody mortality, and delta.agb, but these have not been calculated and reported for all sites for which the appropriate number of censuses are available (n=1 for standing dead wood, n=2 for woody mortality and delta.agb) [but see REFS].

A universal challenge in estimating biomass (living or dead) from forest census data is applying appropriate allometries to convert DBH measurements to biomass. *(Camille/Helene can write this paragraph easily.)*

6.2 Data reporting needs

We recommend that, unless they have some specific reason to do otherwise, researchers calculate and report the values according to IPCC standards:

- adopt common standards for variables like min diameter of deadwood, select soil sampling increments to include a cutoff at 30.
- report 95% CIs, SE, or STD and n
- report C variables in article text, table, or SI table. EFDB cannot accept data digitized from figures

For data synthesis projects, compilation can only be useful to the EFDB if they include all the required, along with transparent description on the methodology applied to derive emission factors (or have a brief description and a reference to the original source) and the original emission factor values are present (not modified/rounded).

Contributing data to ForC and/or EFDB directly will ensure its broader impact. The latter is more efficient for getting data to EFDB, but does not get the data into ForC, where it can be more broadly useful–for example, being used for basic science (e.g., Banbury Morgan et al., 2021; Anderson-Teixeira et al., 2021) or model benchmarking (Fer et al., 2021).

6.3 Database needs

There are plenty of relevant, published data that are not included in ForC. Systematic review of the literature could vastly improve data coverage. *(There are some efforts underway, including a few that Susan can specify.)*

6.4 IPCC

An important challenge is that forests are changing rapidly, and data collected a decaade ago may no longer be relevant, particularly in the cases of C increments and fluxes.

Remote sensing biomass estimates include standing dead wood (Duncanson and MANY_MORE, 2021).

7 Conclusions

The conclusion goes here. You can modify the section name with `\conclusions[modified heading if necessary]`.

Code and data availability. use this to add a statement when having data sets and software code available

Author contributions. (fill this in)

Competing interests. The authors declare no competing interests.

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