Update on

Forest biomass inventories

for use in global carbon observations

Martin Köchy
Johann Heinrich von Thünen Institut — Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute for Agricultural Climate Research (vTI-AK)
Bundesallee 50, 38116 Braunschweig, Germany, martin.koechy@vti.bund.de

1. Abstract

Forest biomass is a major part of the global carbon budget. Therefore, it has been defined as an Essential Carbon Variable (ECaV) that should be sampled in five-year intervals. Forest biomass is reported nationally for the quintannual FAO-Forest Resource Assessments (FRA). The FRA is the most coherent forest assessment globally so far. The reported biomass (in ICPP categories), however is not georeferenced and includes only a qualitative estimate of accuracy. FRA reports are available openly and freely by online access. ICP Forest samples of the forest condition are conducted at the scale of 0.25 ha in Europe and North America. The plots are geo-referenced. Only a subset of plots is used to collect data necessary for calculating biomass. ICP forest plots can differ from plots used for national forest inventories. National forest inventories continue differing in methods and definitions. A library of allometric equations including quantified accuracy seems to be urgently required in international and national assessments. Efforts to standardize definitions internationally are underway. More efforts are necessary to harmonize inventories so that forest biomass can be mapped at 1 km spatial resolution.

2. Introduction

Forest biomass is an Essential Carbon Variable (ECaV, Ciais et al. 2004). The purpose of this document is to describe the current efforts to monitor forest biomass at the global scale and to assess the methods of quality reporting.

The IGOS carbon theme report (Ciais et al. 2004) specifies that forest aboveground biomass is an ECaV. It should be measured every 5 years for managed and unmanaged forests. The required accuracy for site data has not been specified. The corresponding remote-sensing requirements are ±10–25% at 1 km spatial resolution. Data should be reported in units of g/m². Biomass information should be georeferenced.

For a complete forest carbon budget, data on belowground biomass and biomass components (bole, leaves, litter, roots) are also required. This information can be collected directly or through allometric equations (also called "expansion factors", usually with tree diameter at breast height, age, height, or species as independent variables). In addition, information on the carbon content of the biomass is necessary.

3. International programs

FAO Forestry (http://www.fao.org/forestry/en/) is conducting Forest Resource Assessments (FRAs) based on information supplied by individual countries according to standardized guidelines since 1946. Reported units are 1'000'000 metric tons for biomass and 1000 ha for area at the country level. Country reports should be based on national data but may be replaced by expert estimates. This entails that countries may use nationally differing procedures in their forest inventories. Quality control of data is rated subjectively without reference as high, medium, and low (T7.2.1). The FRAs have been conducted at five-year intervals since 1990. Standardization has improved since 1980. The most comprehensive assessment so far is the FRA of the year 2000. FRA2000 included for the first time biomass and carbon calculations (http://www.fao.org/forestry/climatechange/28300/en/). A specialty of FRA2000 was the georeferencing of biomass for tropical regions (Baccini 2000a, Baccini 2000b, Anonymous 2001). FRA2010 will include for the first time a remote sensing component. FAO-Forestry is also building up a database of allometric biomass equations. FRA country reports are available online at the FAO's web site, without access restriction, and free of charge.

FRA2005 and FRA2010 use the IPCC definitions (IPCC 2003) for total, aboveground, and belowground biomass (Anonymous 2004, Anonymous 2007) and also define dead wood biomass (Appendix 1). In addition, FRA2005/2010 define the carbon pool in the aforementioned biomass compartments. Several methods with varying accuracy may be employed for reporting biomass and carbon pools depending on the availability of data (Anonymous 2008). FAO examined the biomass reports of FRA2005 (Marklund and Schoene 2006):

> "The FRA 2005 data set is the most comprehensive global data set to date with country estimates of growing stock, biomass and carbon stocks for three points in time. The quality and reliability of individual figures reported by the countries vary considerably, as many countries do not have good inventory data and therefore must rely partly or entirely on the use of conversion factors and default values. As the errors in country data are unknown, and sometimes large, it was not meaningful to perform a formal statistical error analysis of the estimates presented in this working paper.
>
> The main weakness of the data set is related to the trend estimates. Most of the countries do not have inventory data at two or more points in time, instead one single estimate of stock per hectare has been applied to the forest area for the three reporting years. Reported trends in

stocks therefore often reflect the trends in forest area. This applies particularly to the developing countries.

Another weakness in the data set is the generally weak reporting on carbon in litter and soil; however this is a known information gap. The estimates of carbon in dead wood, litter and soil are also uncertain due to the fact that the default values given by IPCC (2003) are uncertain.

The considerable variation in countries' application of diameter thresholds for growing stock estimates is also a source of uncertainty, and growing stock, biomass and carbon stocks in biomass might therefore be underestimated.

However, and despite the above-mentioned limitations in data availability, the conversion and expansion factors applied by countries for transforming growing stock into stocks of biomass and carbon appears plausible, although there are indications that some pools might be underestimated."

FAO and several other organizations (IPCC, UNFCC, CPF) that need forestry data have begun a process of harmonizing definitions (Schoene 2002). Thus, FRA2010 follows the reporting requirements established by IPCC. It also provides information to the Convention on Biological Diversity. National definitions relevant to forest inventories still differ (Vidal et al. 2008). Cost Action E43 was coordinating the harmonization of National Inventories in Europe 2004–2008 (http://www.metla.fi/eu/cost/e43/reports/MonitoringProgressReport_E43-2008.pdf including citations of published material arising from the Cost Action.). The Forest Data and Information Systems of the Joint Research Center (http://forest.jrc.ec.europa.eu) is contributing to advancing the spatial mapping of forest cover at 25 m resolution and decadal intervals.

ECaVs related to forest biomass are gross and net primary productivity, and the ancillary variables (peak) leaf area index, species composition, canopy cover, canopy height, and soil characteristics. These are collected routinely in Europe, Russia, U.S.A., Canada, and Turkey within the ICP Forest program. The program started in 1985. In Europe it monitors the forest condition on a systematic grid of 16 km × 16 km (level 1) including 800 plots (level 2) with more intensive observations (e.g., height, diameter at breast height). Level 1 plots are monitored annually. Measurement frequency on level 2 plots (50 m × 50 m) depends on the variable (continuously to every ten years). The data are accessible to researchers by request to the Programme Co-ordinating Centre of ICP Forests (http://www.icp-forests.org/MonDat.htm). One condition of data access is that the data are not submitted to other parties. Plot coordinates are released with an accuracy of 1 arcminute (≈ 1.5 km) to protect the privacy of forest owners. ICP Forest currently does not sample biomass directly, but biomass can be calculated from measurements of diameter and height via allometric equations. A system of quality assessment and control has been established. ICP Forest has recognized the need to include data for upscaling of carbon pool information from the assessment plot to the regional scale (Fischer 2008).

The European Space Agency has finished a feasibility study in preparation for a candidate Earth Explorer mission (BIOMASS) to measure aboveground forest biomass using longwave radar (ESA 2009). The

BIOMASS mission, however, competes with two other Earth Explorer candidate missions (CoReH$_2$O for snow, ice and water cycle and PREMIER for trace gas processes in the upper atmosphere). One of these missions will be launched around 2016. BIOMASS, if implemented, will have a spatial resolution of ≤ 61 m × 50 m with a complete coverage of forested areas every 27 or 39 days depending on the implemented concept (ESA 2008).

4. Main conclusions relevant for COCOS and the GEO process

FRA data are reported at the country level. Georeferenced forest biomass data is not yet available at the global level. Countries that conduct national forest inventories by sampling specified points could provide the necessary data in principle. Data privacy of the forest owners, however, may allow the use of data only at an aggregated level. The size of the aggregated level will likely depend on the number of forest owners relative to the spatial extent of the aggregated level.

The accuracy of biomass and other data reported in the FRA is qualitative but it should be quantified. The Swedish Forest Inventory, which has been carried out since 1926 and incorporates much experience, assumes that the reported national volume of timber is underestimated by 1% (Nilsson 2009). One can assume that the reports of other countries are larger or at best similar.

ICP Forest data (level 1, every five years) for calculating biomass at the plot level is available with geo-reference at coarse resolution and only for Europe and North America. The use of the data is restricted. ICP Forest plots do not necessarily coincide with plots used for national forest inventories. This prevents the efficient use of data and resources. The allometric equations necessary for calculating biomass should be collected jointly with FAO. The ICP Forest program provides many of the details needed for calculating carbon budgets. Therefore, similar programs should be set up on other continents. ICP Forest and national inventories should be coordinated in such a way that georeferenced biomass data can be generated at a spatial resolution that satisfies both researchers and forest owners.

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2 Terms and Definitions for the National Reporting tables for FRA 2005

This section provides the terms and definitions used for the 15 tables in FRA 2005 with explanatory notes. The FRA Reporting Tables, to which the term is mainly related, are also indicated.

BIOMASS

Organic material both above-ground and below-ground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc. Biomass includes the pool definition for above - and below - ground biomass.

(IPCC. 2003. *Good Practice Guidance for LULUCF* - Glossary)

The term is mainly related to FRA 2005 National Reporting Table T6.

(Note however that countries are not requested to provide information on the biomass of Litter for FRA 2005)

Above-ground biomass

All living biomass above the soil including stem, stump, branches, bark, seeds, and foliage.

(IPCC. 2003. *Good Practice Guidance for LULUCF* - Glossary)

Explanatory note:

1. Where the forest understorey is a relatively small component of the above-ground biomass, it is acceptable to exclude it, provided this is done in a consistent manner throughout the inventory time series.

The term is mainly related to FRA 2005 National Reporting Table T6.

Below-ground biomass

All living biomass of live roots. Fine roots of less than (suggested) 2mm diameter are sometimes excluded because these often cannot be distinguished empirically from soil organic matter or litter.

(IPCC. 2003. *Good Practice Guidance for LULUCF* - Glossary)

Explanatory notes:
1. May include the below-ground part of the stump.

2. The country may use another threshold value than 2 mm for fine roots, but in such a case the threshold value used must be documented.

The term is mainly related to FRA 2005 National Reporting Table T6.

Dead wood biomass

All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country.

Explanatory note:
1. The country may use another threshold value than 10 cm, but in such a case the threshold value used must be documented.

The term is mainly related to FRA 2005 National Reporting Table T6.

CARBON STOCK

The quantity of carbon in a "pool", meaning a reservoir or system which has the capacity to accumulate or release carbon.

Explanatory note:
1. For FRA 2005 purposes, examples of carbon pools are Living biomass (including Above and below-ground biomass); Dead organic matter (including dead wood and litter); Soils (soils organic matter). The units are mass.

(IPCC. 2003. *Good Practice Guidance for LULUCF* - Glossary)

Carbon in above-ground biomass

Carbon in all living biomass above the soil, including stem, stump, branches, bark, seeds, and foliage.

Explanatory note:
1. Where the forest under-storey is a relatively small component of the above ground biomass carbon pool, it is acceptable to exclude it, provided this is done in a consistent manner throughout the inventory time series.

The term is mainly related to FRA 2005 National Reporting Table T7.

Carbon in below-ground biomass

Carbon in all living biomass of live roots.

Explanatory notes:
1. Includes the below-ground part of the stump.

2. The country may use another threshold value than 2 mm for fine roots, but in such a case the threshold value used must be documented.

3. Fine roots of less than 2 mm diameter are excluded, because these often cannot be distinguished empirically from soil organic matter or litter.

The term is mainly related to FRA 2005 National Reporting Table T7.

Carbon in dead wood biomass

Carbon in all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country.

Explanatory note:
1. The country may use another threshold value than 10 cm, but in such a case the threshold value used must be documented.

The term is mainly related to FRA 2005 National Reporting Table T7.

Carbon in litter

Carbon in all non-living biomass with a diameter less than a minimum diameter chosen by the country in various states of decomposition above the mineral or organic soil. This includes the litter, fumic, and humic layers.

Explanatory note:
1. Live fine roots of less than 2 mm (or other value chosen by the country as diameter limit for below-ground biomass) are included in the litter where they cannot be distinguished from it empirically.

The term is mainly related to FRA 2005 National Reporting Table T7.