

Global Biomass Projections and Forest Carbon Sequestration Potential, 2020-2100

Documentation Revision Date: 2026-10-08

Dataset Version: 1

Summary

This dataset provides annual global projections of live vegetation biomass and forest carbon sequestration potential through 2100 at 1-km resolution under reference and future climate change scenarios. Contemporary forest biomass was initialized using billions of spaceborne lidar observations from NASA's Global Ecosystem Dynamics Investigation (GEDI) and Ice, Cloud and Land Elevation Satellite-2 (ICESat-2), together with global land-cover observations and the Ecosystem Demography model (ED v3.0). Annual biomass was projected from 2021 through 2100 under alternative combinations of future climate, atmospheric CO₂ concentration, and disturbance forcing. The dataset includes annual biomass projections for existing forests and potential new forests, as well as Carbon Sequestration Potential Gap (CSPG2100) products summarizing the projected biomass change between 2020 and 2100. The data are provided in GeoTIFF format.

There are 1170 data files in GeoTIFF format in this dataset.

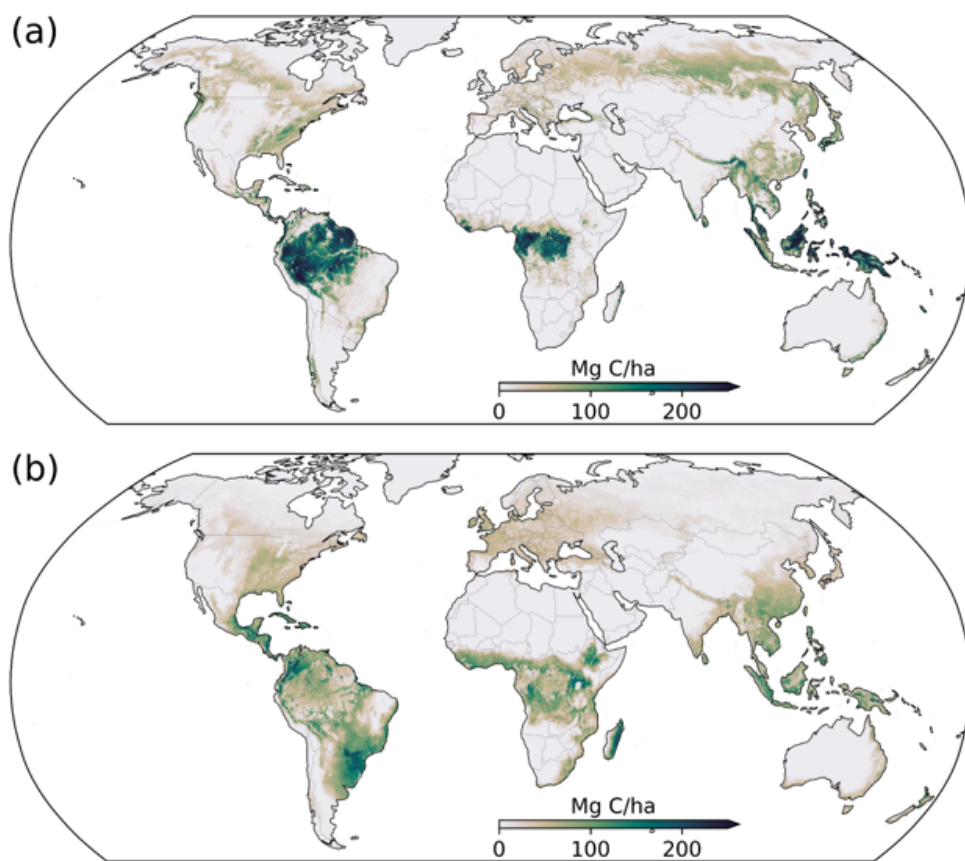


Figure 1. Global forest biomass and carbon sequestration potential under reference conditions. (a) Contemporary forest carbon stocks, including both aboveground and belowground biomass. (b) Future carbon sequestration potential (CSPG) by 2100. CSPG is defined as the difference between potential biomass in 2100 and present-day carbon stocks.

Citation

Ma, L., and G.C. Hurtt. 2026. Global Biomass Projections and Forest Carbon Sequestration Potential, 2020-2100. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/2522>

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1. Dataset Overview

This dataset provides annual global projections of live vegetation biomass and forest carbon sequestration potential through 2100 at 1-km resolution under reference and future climate change scenarios. Contemporary forest biomass was initialized using billions of spaceborne lidar observations from NASA's Global Ecosystem Dynamics Investigation (GEDI) and Ice, Cloud and Land Elevation Satellite-2 (ICESat-2), together with global land-cover observations and the Ecosystem Demography model (ED v3.0). Annual biomass was projected from 2021 through 2100 under alternative combinations of future climate, atmospheric CO₂ concentration, and disturbance forcing. The dataset includes annual biomass projections for existing forests and potential new forests, as well as Carbon Sequestration Potential Gap (CSPG2100) products summarizing the projected biomass change between 2020 and 2100.

Future forest dynamics were simulated by running ED v3.0 forward from the observation-constrained initial conditions, driven by transient climate, atmospheric CO₂ and disturbance forcing from 2020 to 2100. Future land-use change, socioeconomic constraints, and policy limitations were not considered, such that the projections represent the technical biophysical potential for forest carbon sequestration. Natural disturbance processes, including wildfire, were simulated dynamically throughout the simulations.

Project: Carbon Monitoring System

NASA's Carbon Monitoring System (CMS) is designed to make significant contributions in characterizing, quantifying, understanding, and predicting the evolution of global carbon sources and sinks by improving the monitoring of carbon stocks and fluxes. The CMS project uses NASA satellite observations and modeling/analysis capabilities to establish the accuracy, quantitative uncertainties, and utility of products for supporting national and international policy, regulatory, and management activities. CMS data products inform near-term decision-making, market applications, and program development.

Related Publications

Ma, L. et al. 2026. The effects of global climate change on forest carbon sequestration potential in vegetation. Communications Earth & Environment (in process).

Related Datasets

Ma, L., G.C. Hurtt, H. Tang, R. Lamb, A.J. Lister, L.P. Chini, R.O. Dubayah, J. Armston, E. Campbell, L. Duncanson, S.P. Healey, J. O'Neil-Dunne, L. Ott, B. Poulter, and Q. Shen. 2023. Global Forest Aboveground Carbon Stocks and Fluxes from GEDI and ICESat-2, 2018-2021. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/2180>

- Provides contemporary Global Forest Aboveground Carbon Stocks and Fluxes also derived from GEDI and ICESat-2 by the same authors. Future estimates are not included.

2. Data Characteristics

Spatial Coverage: global

Spatial Resolution: 0.01° (~1 km) per pixel

Temporal Coverage: Carbon sequestration potential products, 2020–2100; Biomass projections, 2021-2100

Temporal Resolution: annual

Study Area: Latitude and longitude are given in decimal degrees

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Global	-180	180	80	-60

Data File Information

There are 1170 data files in GeoTIFF (.tif) format. The data file variables and descriptions are provided in Table 1.

Annual biomass

Reference Simulation products are named *Biomass_REF_<forest_component><start_year><end_year>.tif*

Example file name: *Biomass_REF_new_forest_2091_2100.tif*

Future projection scenario products are named *Biomass_<ESM>_<SSP>_<CASE><forest_component><start_year>_<end_year>.tif*

- *<forest_component>* = "existing_forest" or "new_forest."
- *<start_year>* and *<end_year>* are the first and last year represented by the decadal file
- *<ESM>* = CMIP6 Earth System Model: "GFDL-ESM4", "GISS-E2-1-G", "EC-Earth3", or "MPI-ESM1.2-HR"
- *<SSP>* = Shared Socioeconomic Pathway: "SSP126", "SSP245", "SSP370", or "SSP585"
- *<CASE>* = Projection case: "CLIM", "CLIM_CO2", "CLIM_DIST300", or "CLIM_CO2_DIST300"

Example file name: *Biomass_EC-Earth3_SSP126_CLIM_CO2_DIST300_existing_forest_2091_2100.tif*

Each annual biomass GeoTIFF contains one raster band for each calendar year within the corresponding decade. Embedded band descriptions identify the corresponding calendar year.

Carbon Sequestration Potential Gap (CSPG2100)

Reference Simulation products are in two files: *Global_CSPG2100_REF_existing_forest_2020-2100.tif* and *Global_CSPG2100_REF_new_forest_2020_2100.tif*. See Section 5. Data Acquisition, Materials, and Methods for more information about the existing and new forest components.

Future projection scenarios are named *Global_CSPG2100_<forest_component>_<ESM>_<SSP>_<CASE>_2020_2100.tif*

Example file name: *Global_CSPG2100_MPI-ESM1.2-HR_SSP585_CLIM_CO2_new_forest_2020_2100.tif*

Table 1. Variable Descriptions

Variable	Unit	Description
Annual Biomass	kg C m ⁻²	Annual live vegetation biomass carbon, including both above- and belowground, projected from 2021 through 2100 under alternative combinations of future climate, atmospheric CO ₂ concentration, and disturbance forcing. Each GeoTIFF file contains one raster band for each calendar year within the corresponding decade. Embedded band descriptions identify the corresponding calendar year.
CSPG2100	kg C m ⁻²	Carbon sequestration potential gap, calculated as the difference in biomass between 2020 and 2100.

GeoTIFF Characteristics

- Datum: WGS 84
- Map Units: degree
- Bands: 10 (annual biomass); 1 (CSPG2100)
- Data type: Int16
- Scale factor: 0.01; Offset: 0.0
- No data value: -32768

3. Application and Derivation

This dataset supports analyses of global forest carbon sequestration potential and its sensitivity to future climate change. The annual biomass products provide transient projections from 2021–2100 under alternative combinations of climate, atmospheric CO₂ concentration, and disturbance, enabling assessment of the magnitude, spatial distribution, and timing of forest carbon accumulation. The CSPG2100 products summarize the corresponding net biomass change between 2020 and 2100. Separate products are provided for existing forests and potential new forests, supporting assessments of forest-based climate mitigation under alternative future scenarios.

4. Quality Assessment

Contemporary biomass initialized by the height-based framework was evaluated against independent global biomass products (GEDI L4B, GlobBiomass, and ESA CCI Biomass), and there was good agreement in both global biomass totals and their spatial distributions. The projected forest carbon sequestration potential under the Reference Simulation was also compared with previous global estimates and found to be consistent with the range reported in the literature. Additional evaluations of the initialization framework and ED v3.0 have been reported in previous regional and global studies (Hurt et al., 2019; Ma et al., 2021; Ma et al., 2023).

5. Data Acquisition, Materials, and Methods

Contemporary forest biomass was estimated using a height-based initialization approach that integrates lidar observations of forest structure with the Ecosystem Demography model (ED). This approach has been developed and evaluated across regional and global domains (Hurt et al., 2019; Ma et al., 2021, 2023). This study used forest structure from NASA's Global Ecosystem Dynamics Investigation (GEDI) L2A (Dubayah et al., 2021) and Ice, Cloud and Land Elevation Satellite-2 (ICESat-2) ATL08 observations (Neuenschwander et al., 2020) together with the ESA Climate Change Initiative (CCI) global land-cover product (Buchhorn et al., 2020). The global dataset is divided into 10 x 10-degree tiles. Each tile is a GeoTiff file that contains multiple bands corresponding to years between 2020 and 2100. Each tile reports carbon in unit of kg C m⁻² and has a spatial resolution of 0.01 degree per pixel (~1 km at the equator). Due to the sampling nature of two lidar missions and incomplete spatial coverage, gaps and strips in AGB estimates are filled by spatial interpolation. This interpolation first upscaled AGB from 0.01 degree to 0.1 degree by taking the average, then interpolated back to 0.01 degree with bilinear method. For areas where gaps still existed, this step was repeated but upscaled to 0.5 degree. The ED model is a process-based demographic ecosystem model that simulates vegetation growth, mortality, regeneration, and succession (Hurt et al., 1998; Moorcroft et al., 2001; Ma et al., 2022). This study used ED v3.0, a recently developed version calibrated and evaluated for global applications (Ma et al., 2022).

Future forest dynamics were simulated by running ED v3.0 forward from the observation-constrained initial conditions, driven by transient climate, atmospheric CO₂, and disturbance forcing from 2020 to 2100. Future land-use change, socioeconomic constraints, and policy limitations were not considered, such that the projections represent the technical biophysical potential for forest carbon sequestration. Natural disturbance processes, including wildfire, were simulated dynamically throughout the simulations.

The forward simulations include one Reference Simulation, in which present-day climate, atmospheric CO₂ concentration, and disturbance are repeated throughout the simulation period, and 64 future projection scenarios representing all combinations of four projection cases, four Shared Socioeconomic Pathways (SSPs), and four CMIP6 Earth System Models (ESMs). The four projection cases successively incorporate 1) future climate only (CLIM), 2) future climate and atmospheric CO₂ (CLIM_CO2), 3) future climate and increased disturbance (CLIM_DIST300), and 4) future climate, atmospheric CO₂, and increased disturbance (CLIM_CO2_DIST300). Future climate forcing was derived from four bias-corrected CMIP6 Earth System Models (GFDL-ESM4, GISS-E2-1-G, EC-Earth3, and MPI-ESM1.2-HR) under four Shared Socioeconomic Pathways (SSP1-2.6, SSP2-4.5,

SSP3-7.0, and SSP5-8.5). The disturbance sensitivity experiments prescribe a linear increase in the background non-fire disturbance rate to 300% of its present-day value by 2100, while wildfire and other dynamic disturbance processes continue to be simulated by ED.

Two forest components were simulated separately. Existing forests correspond to the contemporary forest extent derived from the global land-cover product and remain forest throughout the simulations, allowing continued growth, mortality, and succession. New forests correspond to contemporary cropland, grassland, and shrubland, where natural forest regeneration is permitted during the simulations to estimate the technical biophysical potential for additional carbon sequestration. Existing forest extent is fixed throughout the simulations, whereas new forest area expands dynamically through simulated natural regeneration.

6. References

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