Greenhouse Gas Emissions and Removals from Forest Land, Woodlands, and Urban Trees in the United States, 1990 - 2021: Estimates and Quantitative Uncertainty for Individual States, Regional Ownership Groups, and National Forest System Regions

Citation:

Walters, Brian F.; Domke, Grant M.; Greenfield, Eric J.; Smith, James E.; Ogle, Stephen M. 2023. Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2021: Estimates and quantitative uncertainty for individual states, regional ownership groups, and National Forest System regions. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2023-0020

Abstract:

As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), the United States has been reporting an economy-wide inventory of greenhouse gas (GHG) emissions and removals since the mid-1990s (U.S. EPA 2023). Estimates of GHG emissions and removals from forest land, woodlands in the grassland category, and urban trees in settlements are compiled by U.S. Department of Agriculture (USDA) Forest Service researchers and are based primarily on National Forest Inventory (NFI) data collected and maintained by the Forest Inventory and Analysis (FIA) program within the USDA Forest Service. The estimates of GHG emissions and removals provided in this publication are based on the compilation reported in the Land Use, Land-Use Change, and Forestry chapter of the U.S. Environmental Protection Agency (2023) submission to the UNFCCC. Included in this package are 18 tables of estimates and 2 tables of quantitative uncertainties.

Resource Update publication related to these estimates:

Domke, Grant M.; Walters, Brian F.; Giebink, Courtney L.; Greenfield, Eric J.; Smith, James E., Nichols, Michael C.; Knott, Jon A.; Ogle, Stephen M.; Coulston, John W.; Steller, John. 2023. Greenhouse gas emissions and removals from forest land, woodlands, urban trees, and harvested wood products in the United States, 1990-2021. Resour. Bull. WO-101. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 10 p. https://doi.org/10.2737/WO-RB-101

For detailed descriptions of the methods and models used to produce these estimates:

U.S. Environmental Protection Agency [U.S. EPA]. 2023. Inventory of U.S. greenhouse gas emissions and sinks: 1990–2021. EPA 430-R-23-002. Washington, DC: U.S. Environmental Protection Agency. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021 (accessed 13 April 2023)

Estimate and Quantitative Uncertainty Table Notes for All Tables:

- Data are left blank if there were no observations.
- Estimates of net flux and emissions are provided through 2021. Estimates of carbon stocks and land areas are provided through 2022.
- Managed forest land for U.S. Territories is not currently included in Section 6.1 Representation of the U.S. Land Base of the "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021" (U.S. EPA 2023), therefore U.S. Territories are not included here.
- There is not sufficient Forest Inventory and Analysis data to include estimates of forest ecosystem carbon (C) stocks, C stock changes, or other emissions for the state of Hawaii at this time.

- Area estimates of land representation in the current Inventory (U.S. EPA 2023) include the state of Hawaii and more resolved land use conversions for the states of Alaska and Wyoming, so there are differences in the area estimates reported in this package and those reported in Section 6.1 Representation of the U.S. Land Base in the U.S. EPA inventory report.
- Estimates for each state may not be available for every state-level table. This may be due to the resolution of the available data, a lack of observations of the particular land use category or land use conversion category, or there was insufficient data.
- The disaggregated estimates will not sum to the national total due to independent rounding.
- The forest ecosystem C stocks and stock changes on *Forest Land Remaining Forest Land*, *Land Converted to Forest Land*, and *Forest Land Converted to Land* do not include trees on non-forest land (e.g., agroforestry systems and settlement areas).
- Negative values indicate net C uptake (i.e., a net removal of C from the atmosphere).

Estimate and Quantitative Uncertainty Table Notes for Individual Tables:

Net CO_2 and C Flux from Forest Pools in *Forest Land Remaining Forest Land* by State (MMT CO_2 Eq. and MMT C)

Filename: FRF_net_flux_by_State.csv

- Total net flux is an estimate of the actual net flux between the total forest C pool and the atmosphere
- Forest ecosystem C stocks on managed forest land in Alaska were compiled using the gain-loss method as described in Annex 3.13 (US EPA 2023)
- Flux estimates in the drained organic soil pool include C stock changes from both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*

Quantitative Uncertainty Estimates for Net CO_2 Flux from *Forest Land Remaining Forest Land* by State, 2021 (MMT CO_2 Eq. and Percent)

Filename: FRF_net_flux_by_State_uncertainty_2021.csv

- Range of flux estimates predicted through a combination of sample-based and model-based uncertainty for a 95 percent confidence interval, IPCC Approach 1

C Stocks in *Forest Land Remaining Forest Land* by State (MMT C)

Filename: FRF_stock_by_State.csv

- Population estimates compiled using FIA data are assumed to represent stocks as of January 1 of the inventory year
- Flux is the net annual change in stock. Thus, an estimate of flux for 2021 requires estimates of C stocks for 2021 and 2022.
- Forest ecosystem C stocks on managed forest land in Alaska were compiled using the gain-loss method as described in Annex 3.13 (US EPA 2023)

Net CO_2 and C Flux from Woodland Pools in *Woodlands Remaining Woodlands* by State (MMT CO_2 Eq. and MMT C)

Filename: WRW_net_flux_by_State.csv

- Estimates of C stock change in woodlands, which are included in the Grassland land use category, were compiled using the same methods and models as those in the *Forest Land Remaining Forest Land* category
- Total net flux is an estimate of the actual net flux between the total woodland C pool and the atmosphere

C Stocks in *Woodlands Remaining Woodlands* by State (MMT C)

Filename: WRW_stock_by_State.csv

- Estimates of C stocks in woodlands, which are included in the Grassland land use category, were compiled using the same methods and models as those in the *Forest Land Remaining Forest Land* category
- Population estimates compiled using FIA data are assumed to represent stocks as of January 1 of the inventory year
- Flux is the net annual change in stock. Thus, an estimate of flux for 2021 requires estimates of C stocks for 2021 and 2022.

Land Use and Land-Use Change Area for the Managed Land Base by State (Thousands of Hectares)

Filename: LULUC_area_by_State.csv

- The abbreviations are *F* for Forest Land, *C* for Cropland, *G* for Grassland, *O* for Other Lands, *S* for Settlements, and *W* for Wetlands. Lands remaining in the same land-use category are identified with the land-use abbreviation given twice (e.g., *FF* is *Forest Land Remaining Forest Land*), and land-use change categories are identified with the previous land use abbreviation followed by the new land-use abbreviation (e.g., *CF* is *Cropland Converted to Forest Land*)
- Total forest land is the sum of *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*
- All land areas reported in this table are considered managed
- A planned improvement is underway to deal with an exception for Wetlands, which based on the definitions for the current U.S. Land Representation Assessment includes both managed and unmanaged lands
- Area estimates disaggregated into *Forest Land Remaining Forest Land*, *Land Converted to Forest Land*, and *Forest Land Converted to Land* are not available in Alaska or Wyoming

CO_2 and Non-CO_2 Emissions from Forest Fires by State (MMT CO_2 Eq.)

Filename: Fire_CO2_and_NonCO2_emissions_CO2eq_by_State.csv

- These estimates include CO_2 and non-CO_2 emissions from forest fires on *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*
- Empty cells indicate no observations in the Monitoring Trends in Burn Severity (MTBS) database or the MODIS burned area mapping product. The MTSB database only includes fires that are at least 400 ha in size in the western United States and 200 ha in size in the eastern United States.

Quantitative Uncertainty Estimates of CO_2 and Non-CO_2 Emissions from Forest Fires by State, 2021 (MMT CO_2 Eq. and Percent)

Filename: Fire_CO2_and_NonCO2_emissions_CO2eq_by_State_uncertainty_2021.csv

- These estimates include CO_2 and non-CO_2 emissions from forest fires on *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*
- Range of flux estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval, IPCC Approach 2

Non-CO_2 Emissions from Forest Fires by State (kt)

Filename: Fire_NonCO2_emissions_kt_by_State.csv

- These estimates include non-CO_2 emissions from forest fires on *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*
- Empty cells indicate no observations in the Monitoring Trends in Burn Severity (MTBS) database or the MODIS burned area mapping product. The MTSB database only includes fires that are at least 400 ha in size in the western United States and 200 ha in size in the eastern United States.

Non-CO_2 Emissions from Drained Organic Forest Soils by State (MMT CO_2 Eq.)

Filename: DOS_NonCO2_emissions_by_State.csv

- These estimates include non-CO_2 emissions from drained organic soils on *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*

Net Flux from Forest C Pools in *Land Converted to Forest Land* by Land Use Change Category and State (MMT CO_2 Eq. and MMT C)

Filename: LCF_net_flux_by_State.csv

- The *Grassland Converted to Forest Land* category includes woodlands converted to forest land
- Estimates of net flux in the Soil (Mineral) forest carbon pool are not available in the *Wetlands Converted to Forest Land* category
- State total net flux and total net flux in the Soil (Mineral) forest carbon pool do not include Soil (Mineral) net flux estimates from land use conversion categories in which they are not available
- It is not possible to separate emissions from drained organic soils between *Forest Land Remaining Forest Land* and *Land Converted to Forest Land* so estimates for all organic soils are included in the tables for net flux on *Forest Land Remaining Forest Land*

Net Flux from Forest C Pools in *Forest Land Converted to Land* by Land Use Change Category and State (MMT CO_2 Eq. and MMT C)

Filename: FCL_net_flux_by_State.csv

- The *Forest Land Converted to Grassland* category includes forest land converted to woodlands
- Estimates of net flux in the Soil (Mineral) forest carbon pool are not available in the *Forest Land Converted to Other Lands* and *Forest Land Converted to Wetlands* categories
- State total net flux and total net flux in the Soil (Mineral) forest carbon pool do not include Soil (Mineral) net flux estimates from land use conversion categories in which they are not available
- It is not possible to separate emissions from drained organic soils between *Forest Land Remaining Forest Land* and *Forest Land Converted to Land* so estimates for all organic soils are included in the tables for net flux on *Forest Land Remaining Forest Land*

Net CO_2 and C Flux from Settlement Trees in *Settlements Remaining Settlements* by State (MMT CO_2 Eq. and MMT C)

Filename: Settlement_tree_net_flux_by_State.csv

- These estimates include net CO_2 and C flux from settlement trees on *Settlements Remaining Settlements* and *Land Converted to Settlements*

Net CO_2 and C Flux from Forest Pools in *Forest Land Remaining Forest Land* by Region and Ownership Group (MMT CO_2 Eq. and MMT C)

Filename: FRF_net_flux_by_Region_and_OwnershipGroup.csv

- Total net flux is an estimate of the actual net flux between the total forest C pool and the atmosphere
- There is not sufficient Forest Inventory and Analysis data in Interior Alaska to determine ownership, therefore the Pacific Coast region only includes Coastal Alaska

C Stocks in *Forest Land Remaining Forest Land* by Region and Ownership Group (MMT C)

Filename: FRF_stock_by_Region_and_OwnershipGroup.csv

- Population estimates compiled using FIA data are assumed to represent stocks as of January 1 of the inventory year
- Flux is the net annual change in stock. Thus, an estimate of flux for 2021 requires estimates of C stocks for 2021 and 2022.
- There is not sufficient Forest Inventory and Analysis data in Interior Alaska to determine ownership, therefore the Pacific Coast region only includes Coastal Alaska

Area of *Forest Land Remaining Forest Land* by Region and Ownership Group (Thousands of Hectares)

Filename: FRF_area_by_Region_and_OwnershipGroup.csv

- All land areas reported in this table are considered managed
- There is not sufficient Forest Inventory and Analysis data in Interior Alaska to determine ownership, therefore the Pacific Coast region only includes Coastal Alaska

Net CO_2 and C Flux from Forest Pools in *Forest Land Remaining Forest Land* by National Forest System Region (MMT CO_2 Eq. and MMT C)

Filename: FRF_net_flux_by_National_Forest_System_Region.csv

- Total net flux is an estimate of the actual net flux between the total forest C pool and the atmosphere

C Stocks in *Forest Land Remaining Forest Land* by National Forest System Region (MMT C)

Filename: FRF_stock_by_ National_Forest_System_Region.csv

- Population estimates compiled using FIA data are assumed to represent stocks as of January 1 of the inventory year
- Flux is the net annual change in stock. Thus, an estimate of flux for 2021 requires estimates of C stocks for 2021 and 2022.

Area of *Forest Land Remaining Forest Land* by National Forest System Region (Thousands of Hectares)

Filename: FRF_area_by_ National_Forest_System_Region.csv

- All land areas reported in this table are considered managed