

5

Land Use, Land-Use Change, and Forestry (LULUCF)

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Suggested Citation

Steller, J., Rewcastle, K., Barbieri, L., & Patel, A. (2026). Chapter 5. Land Use, Land-Use Change and Forestry. In Desai et al., *Methodology report for greenhouse gas inventory and analysis by U.S. state: 1990–2024*. Digital Repository at the University of Maryland. https://doi.org/10.13016/5wlk-9ksj

5. Land Use, Land-Use Change, and Forestry

This chapter describes the methods applied to estimate state-level GHG fluxes resulting from land use and land-use change within states according to changes within and conversions between all land use types, including:

- Forest land,[11]
- Cropland,
- Grassland,
- Wetlands,
- Settlements, and
- Other land.

More information on national-level emissions and removals and associated methods is available in Chapter 6 of the national-level *GHGIA.*

Methodology

Table 5-1 summarizes the different approaches used to estimate state-level LULUCF emissions and removals. Overall, the methods used to develop state-level estimates are consistent with those used in EPA (2024). For some categories, including forest carbon, cropland, grassland and some settlements categories, state and national estimates are both developed using the same underlying data and methods for portions or all of the time series. In these cases, state-level estimates are not derived by disaggregating the national-level *GHGIA* estimate to individual states. Rather, the national-level *GHGIA* methodology uses geographically detailed data to develop estimates that can be aggregated to both the state and national levels. These instances are noted in Table 5-1 as using the same methods as the national-level *GHGIA*. This designation indicates that state and national estimates are developed using the same underlying methods. For other categories, national-level *GHGIA* estimates are disaggregated or allocated to the state level using activity data or geographic proxies. State completeness is consistent with the national-level *GHGIA;* see Annex 1.

For users seeking a comprehensive technical understanding of the compilation of the *GHGIA by State* data, this methodology report is best read in conjunction with the corresponding sections of the three references provided in Table 5-2. The *GHGIA by State* emission and sink estimates are compiled to be consistent with the latest national-level *GHGIA* data and largely apply and extend methodologies and data previously published by EPA at the national and state levels. Methodological detail is only included in this document for new sources not included in EPA (2024). Unless otherwise noted, readers should refer to EPA (2024) for detailed descriptions of disaggregation methodologies. Where previously published methods remain unchanged, CGS summarizes the disaggregation approaches rather than repeating information from the latest national-level inventory report or the previous state-level methodology report. Recalculations at the national-level *GHGIA* that impact state-level estimates are discussed in the national-level *GHGIA* Chapter 6.

11 U.S. Forest Service develops state-level estimates for the forest land as part of their U.S. Forest Service Resource Bulletin (Domke et al., 2026 published online at https://doi.org/10.2737/WO-RB-103), including state-level data (Walters et al., 2026): https://www.fs.usda.gov/rds/archive/catalog/RDS-2026-0032. This dataset also includes state-level uncertainty estimates for forest ecosystem carbon stock changes (fluxes) and non-CO_2 emissions from forest fires under the Forest Land Remaining Forest Land category.

Table 5-1: Methodology Summary for Estimating State-Level LULUCF Sector GHG Emissions and Sinks

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
Forest land						
Forest land and lands converted to forest land (*GHGIA* Sections 6.2.1 and 6.2.2)	Forest ecosystem carbon stock change	CO_2	State-level carbon stock change estimates are developed using the same method as the national-level *GHGIA*, which is consistent with U.S. Forest Service Forest Inventory and Analysis (FIA) data (Walters et al., 2026).	Yes	Revisions to the time series are due to the incorporation of updated FIA data. In addition, a consistent methodology was utilized for all of CONUS (see national-level *GHGIA* for more details). These changes are reflected in the 1990–2023 time series.	See Walters et al., 2026
	Harvested wood products carbon stock change	CO_2	State-level carbon stock change estimates are developed using a proxy approach based on methodology from the SIT to disaggregate the national HWP estimate (see methodological description following this table).	Newly added	This is a newly added state-level estimate. Previously, it was only estimated at the national level. This is an area of active research and we expect estimates to change over time with methodological refinements.	N/A
	Non-CO_2 emissions from forest fires	CH_4 N_2O	State-level emissions are estimated using the same method as the national-level *GHGIA*, which is consistent with U.S. Forest Service data (Walters et al., 2026).	Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). Revisions to the time series are due to	See Walters et al., 2026

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
					incorporation of updated FIA data. These changes are reflected in the 1990–2023 time series.	
	Nitrogen additions to forest soils	N_2O	Proxy approach. National-level *GHGIA* emissions were evenly distributed to the states included in the national nitrogen additions to forest soils analysis (see methodological description below).	Newly added	This is a newly added state-level estimate. Previously, it was only estimated at the national level.	N/A
	Non-CO_2 drained organic soils	CH_4 N_2O	State-level emissions are estimated using the same method as the national-level *GHGIA*, which is consistent with U.S. Forest Service data (Walters et al., 2026).	Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). Revisions to the time series are due to incorporation of updated FIA data. These changes are reflected in the 1990–2023 time series.	See Walters et al., 2026

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
Cropland						
Cropland and lands converted to cropland (*GHGIA* Sections 6.3.1 and 6.3.2)	Biomass carbon stock change	CO_2	State-level carbon stock change estimates are developed based on a combination of approaches across the time series**.** **1990–2017:** State-level stock change estimates are developed using the same methods as the national-level *GHGIA*. **2018–2024:** National-level *GHGIA* stock change estimates were allocated to states based on each state's average share of national cropland biomass carbon stock changes over the last three years for which state-level estimates were available (2015–2017).	**1990–2017:** No **2018–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2018–2023:** Revisions to the time series are due to updates to the national-level *GHGIA* (2026) forecasting approach (see *GHGIA* Box 5-1 and Section 6.3). These national-level changes are reflected in the state-level estimates.	N/A
	Dead organic matter (DOM) carbon stock change	CO_2	State-level carbon stock change estimates are developed based on a combination of approaches across the time series.	**1990–2017:** No **2018–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024).	N/A

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
			same methods as the national-level *GHGIA*. **2018–2024:** National-level *GHGIA* stock change estimates were allocated to states based on each state's average share of national cropland DOM carbon stock changes over the last three years for which state-level estimates were available (2015–2017).		**2018–2023:** Revisions to the time series are due to updates to the national-level *GHGIA* forecasting approach (see *GHGIA* Box 5-1 and Section 6.3). These national-level changes are reflected in state-level estimates.	
	Soils carbon stock change	CO_2	State-level carbon stock changes are estimated using a combination of methods across the time series. **1990–2020:** State-level stock changes are estimated using the same methods as the national-level *GHGIA*, utilizing prior runs of the Daycent model. **2021–2024:** National-level *GHGIA* stock change estimates were allocated to states based on each state's average share	**1990–2020:** No **2021–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2021–2023:** Revisions to the time series are due to updates to the national-level *GHGIA* forecasting approach for the years beyond the available Daycent model outputs (see *GHGIA* Box 5-1 and Section 6.3). These national-level changes are reflected in state-level estimates.	N/A

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
			of national cropland soil carbon stock changes over the last three years for which state-level Daycent outputs were available (2018–2020).			
Grassland						
Grassland and lands converted to grassland (*GHGIA* Sections 6.4.1 and 6.4.2)	Biomass carbon stock change	CO_2	State-level carbon stock changes are estimated based on a combination of approaches over the time series**.** **1990–2017:** State-level stock change estimates are developed using the same methods as the national-level *GHGIA*. This approach is consistent with the approach previously applied in EPA (2024). **2018–2024:** National-level *GHGIA* stock change estimates were allocated to states based on each state's average share of national grassland biomass carbon stock changes over the last three years for which state-level estimates were available (2015–2017).	**1990–2017:** No **2018–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2018–2023:** Revisions to the time series are due to updates to the national-level *GHGIA* forecasting approach (see *GHGIA* Box 5-1 and Section 6.4.1 and 6.4.2). These national-level changes are reflected in state-level estimates.	N/A

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
	Dead organic matter (DOM) carbon stock change	CO_2	State-level carbon stock changes are estimated based on a combination of approaches across the time series. **1990–2017:** State-level stock changes are estimated using the same methods as the national-level *GHGIA*. **2018–2024:** National-level *GHGIA* stock change estimates were allocated to states based on each state's average share of national grassland DOM carbon stock changes over the last three years for which state-level estimates were available (2015–2017).	**1990–2017:** No **2018–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2018–2023:** Revisions to the time series are due to updates to the national-level *GHGIA* forecasting approach (see *GHGIA* Box 5-1 and Section 6.4.1 and 6.4.2). These national-level changes are reflected in state-level estimates.	N/A
	Soils carbon stock change	CO_2	State-level carbon stock changes are estimated based on a combination of approaches across the time series. **1990–2020:** State-level stock change estimates are developed using the same methods as the national-level *GHGIA*, utilizing prior runs of the Daycent model.	**1990–2020:** No **2021–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2021–2023:** Revisions to the time series are due to updates to the national-level *GHGIA* forecasting approach for the years beyond the available Daycent model	N/A

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
			2021–2024: National-level *GHGIA* stock change estimates were allocated to states based on each state's average share of national grassland soil carbon stock changes over the last three years for which state-level Daycent outputs were available (2018–2020).		outputs (see *GHGIA* Box 5-1 and Section 6.4.1 and 6.4.2). These national-level changes are reflected in state-level estimates.	
Grassland remaining grassland (*GHGIA* Section 6.4.1)	Non-CO_2 emissions from grassland fires	CH_4 N_2O	State-level emissions are estimated based on a combination of approaches across the time series. **1990–2020:** State-level emissions are estimated using the same methods as the national-level *GHGIA*. This approach is consistent with the approach previously applied in EPA (2024). **2021–2024:** National-level *GHGIA* emissions estimates were allocated to states based on each state's average share of national grassland fire emissions over the last three years for which state-level emissions estimates were available (2018–2020).	**1990–2020:** No **2021–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2021–2023:** Revisions to the time series are due to updates to the national-level *GHGIA* forecasting approach (see *GHGIA* Box 5-1 and Section 6.4.1). These national-level changes are reflected in state-level emissions estimates.	N/A

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
Wetlands						
Wetlands and lands converted to wetlands (*GHGIA* Sections 6.5.1 and 6.5.2)	Coastal wetlands	CO_2 CH_4	State-level emissions and removals are estimated using the same methods as the national-level *GHGIA* for the whole 1990–2024 time series, utilizing geospatial data from NOAA Coastal Change Analysis Program (C-CAP).	**1990–2016:** No **2017–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2017–2023:** Revisions to the time series are due to the incorporation of the latest 2021 NOAA C-CAP data and interpolations between available NOAA data years in the national-level *GHGIA*. This resulted in recalculations to the previously reported 2017–2023 estimate. These changes are reflected in the state-level estimates.	
Wetlands remaining wetlands (*GHGIA* Section 6.5.1)	Aquaculture	N_2O	State-level emissions are estimated based on a proxy approach. The 1990–2024 state-level estimates are allocated to states using state-level aquaculture sales data from USDA and aquaculture production data from NOAA (see methodological description below).	Newly added	This is a newly added state-level emission estimate. Previously, it was only estimated at the national level.	E-6: Aquaculture Production Data

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
Wetlands remaining wetlands (*GHGIA* Section 6.5.1)	Peatlands	CO_2 CH_4 N_2O	State-level emissions are estimated using a hybrid approach across the 1990–2024 time series. The 1990–2024 state-level emissions estimates were developed using a combination of state-level peat production and state population data.	**1990–2021:** No **2022–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2022–2023:** Revisions to the time series are due to incorporation of updated USGS peat production activity data and updates to Census Bureau population data into the national-level *GHGIA*. These changes are reflected in the state-level estimates.	E-7: Peat Production Data
Wetlands and lands converted to wetlands (*GHGIA* Sections 6.5.1 and 6.5.2)	Flooded Lands	CO_2 CH_4	State-level emissions are estimated using the same methods as the national-level *GHGIA*, utilizing geospatial data from various data sources.	Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). Revisions to the time series are due to a re-run of the national-level *GHGIA* flooded lands analysis to reflect waterbody ages. This analysis resulted in minimal recalculations. This is reflected in the state-level emissions estimates.	See national-level *GHGIA* CSV tables 6-29, 6-30, 6-38, and 6-39.

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
Settlements						
Settlements and lands converted to settlements (*GHGIA* Sections 6.6.1 and 6.6.2)	Soil carbon stock change	CO_2	State-level carbon stock changes are estimated based on a combination of approaches across the time series**.** **1990–2020:** State-level stock changes are estimated using the same methods as the national-level *GHGIA*. **2021–2024:** National-level *GHGIA* stock changes were allocated to states based on each state's average share of national settlements soil carbon stock changes over the last three years for which state-level estimates were available (2018–2020).	**1990–2020:** No **2021–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2021–2023:** Revisions to the time series are due to updates to the national-level *GHGIA* forecasting approach (see *GHGIA* Box 5-1 and Section 6.6.1 and 6.6.2). These national-level changes are reflected in the state-level estimates.	N/A
Settlement remaining settlements (*GHGIA* Section 6.6.1)	Settlement trees carbon stock change	CO_2	State-level carbon stock changes are estimated using the same methods as the national-level *GHGIA* for the whole 1990–2024 time series, utilizing FIA, National Land Cover Database (NLCD) tree cover, and settlement area data.	No	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). For 2024, area estimates by state were updated to calculate percent settlement tree cover	N/A

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
					area by state and estimate net CO_2 fluxes (carbon stock changes).	
Settlements remaining settlements (*GHGIA* Section 6.6.1)	Soil N_2O	N_2O	State-level emissions are estimated based on a combination of approaches across the time series**.** **1990–2020:** State-level emissions are estimated using the same methods as the national-level *GHGIA*. **2021–2024:** National *GHGIA* emissions estimates were allocated to states based on each state's average share of national settlement soil N_2O emissions over the last three years for which state-level estimates were available (2018–2020).	**1990–2020:** No **2021–2023:** Yes	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024). **2021–2023:** Revisions to the time series are due to updates to the national-level *GHGIA* forecasting approach (see *GHGIA* Box 5-1 and Section 6.6.1). These national-level changes are reflected in the state-level emissions estimates.	N/A

Category	Subcategory/ Carbon Pool	Gas	Disaggregation Approach	Changes to 1990–2023 estimates from previously published EPA GHGI by state?	Additional Information	Data Appendices
Settlements remaining settlements (*GHGIA* Section 6.6.1)	Landfilled yard trimmings and food scraps carbon stock change	CO_2	Proxy approach. State-level carbon stock changes are estimated by disaggregating national-level *GHGIA* stock change estimates using each state's share of national "settlement" area.	No	No changes were made to the disaggregation methods, and the approach is consistent with that used in EPA (2024).	N/A

Note: LULUCF CO_2 estimates ("Gas" column in Table 5-1) reflect carbon stock changes when described in the "Subcategory/Carbon Pool" column and may therefore be emissions of CO_2 or removals (i.e., sequestration) of CO_2.

Table 5-2: Key References for Data Users

Geographic Scope	Report	Publication Source	Publication Date	What to Read
State	Methodology Report Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1990–2022	EPA (2024)	September 2024	Chapter 1 (Introduction) and Chapter 5 (LULUCF) *sector/source-level "Background", "Methods/* Approach" and "Uncertainty"
National	Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990–2023	EPA (2025)	May 2025 (FOIA Release)	Chapter 6 (LULUCF) source category-level upfront discussion and "Methodology and Time-Series Consistency" and "Uncertainty" sections as appropriate
National	Greenhouse Gas Inventory and Analysis for the United States: 1990–2024 (*GHGIA*)	CGS (Desai et al, 2026)	April 2026	Chapter 6 (LULUCF) source category-level "Methods," "Recalculation," and "Uncertainty" sections as appropriate, and "Future Areas for Improvement"

Methodology for newly added sources

This section elaborates on methods for calculating sources and/or sinks included in the LULUCF sector that were not included or estimated in previous disaggregated data published by EPA (2024). For information on disaggregation methods for all other sources, the methodology outlined by EPA (2024) still applies, but in some cases were updated for different portions of the 1990–2024 time series, as described in Table 5-1.

Forest Land Remaining Forest Land, Harvested Wood Products. The methods to compile state-level carbon stock change estimates for harvested wood products (HWP) are based on the default data from the State Inventory Tool (SIT) (CGS, 2026) and then scaled to match the national HWP carbon flux totals in the national-level *GHGIA* (Desai et al., 2026), consistent with data from Walters et al. (2026). The default data from SIT come from 1987, 1992, and 1997 Forest Service data to estimate average annual stock change for the time period between 1990–1992, 1993–1997, and 1998 to present. These average annual stock change estimates by state were then scaled to the national estimates from the national-level *GHGIA* based on the relative proportion of those state SIT estimates to total aggregated (national-level) SIT estimates. SIT only provides total wood products estimates and does not disaggregate by HWP as products in use and products in solid waste disposal sites (SWDS). To disaggregate HWP to these two subcategories, the proportion of these two categories to the national HWP total from the national-level *GHGIA* was applied equally across all states; changes to the relative proportion of HWP products in use and products in SWDS are reflected at the state level across the 1990 through present time series.

Forest Land Remaining Forest Land, Nitrogen Additions to Forest Soils. Nitrogen additions to forest soils are estimated by taking the total from the national-level *GHGIA* and allocating those emissions evenly to states in the Southeastern U.S., Washington, and Oregon. These are the states included in the nitrogen additions estimates from EPA (2025), reflecting those southeastern states with pine plantations and states with commercial Douglas-fir stands in the Pacific Northwest.

Coastal Wetlands Remaining Coastal Wetlands, N_2O Emissions from Aquaculture. Estimates were disaggregated from the national-level *GHGIA* total using a proxy approach. State-level aquaculture production was estimated using the USDA Census of Aquaculture for the five available census years (USDA, 1998; 2005; 2013; 2018; and 2023). Food-size aquaculture sales data were extracted for the ten highest-volume aquaculture species reported in NOAA's annual national production summaries (see national-level *GHGIA* methodology for more information on the use of NOAA for national activity data): catfish, trout, tilapia, striped bass, oysters, clams, shrimp, mussels, crawfish and salmon. For states where sales data were withheld, state-level sales were estimated by applying the state's farm proportion of national farms to the reported national sales for that species. Once all state sales values were either reported or estimated, each state's proportion of the national sales total was calculated and multiplied by the corresponding national annual production (in pounds) for that species to estimate state-level production. The remaining years in the time series, for which USDA Census of Aquaculture data were not available, were estimated by applying each state's proportion of national production from the more recent available census year to the corresponding national annual production estimates.

Comparison to national totals

Quality control procedures were implemented to review changes to the time series and confirm state-level LULUCF estimates. Issues identified during these checks were addressed, and errors were corrected (e.g., computational formula errors, transcription errors, etc.).

The state-level LULUCF calculations include estimates of CO_2 emissions from drained organic soils, which resulted in GHG estimates that generally align with total estimates in the national-level *GHGIA* but present small differences. Furthermore, independent rounding of the state-level estimates also presents small differences between the total state-level estimates and the national-level *GHGIA*.

Future areas for improvement

Areas for improving state-level estimates are the same as those presented in Section 6.1 of the national-level *GHGIA* (Desai et al., 2026), including improvement of geographic completeness, given that many state-level LULUCF category estimates utilize the same methodological approach as the national-level *GHGIA*. Some state-level planned improvements for LULUCF include:

- Improving state-level estimates to HWP based on ongoing research.
- Refining the coastal wetlands aquaculture approach to reflect only coastal states, which requires revisiting USDA and NOAA data, as well as the national aquaculture N_2O estimation approach.
- Better integrating data between waste sector landfills and LULUCF sector landfilled yard trimming and food scraps, to potentially leverage activity data and ensure consistency across sectors.
- Implementing a new cropland and grassland soil carbon stock change modeling framework, leveraging publicly available cropland and grassland spatial extent and management information.

- Revising the grassland fire non-CO_2 emission estimation framework by leveraging the Wildland Fire Emissions Inventory System (v2.2025.10).

References

The references listed below only include new references used for compiling and updating the current *GHGIA by State*. Full citations for all references relevant to compiling national-level LULUCF estimates are found at the end of Chapter 6 (LULUCF) of the national-level *GHGIA* (Desai et al., 2026) and its Annexes 5.16 to 5.17. The national-level *GHGIA* is available online at https://ghgi.cgs.umd.edu/.

General

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Forest Land Remaining Forest Land and Land Converted to Forest Land

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Coastal Wetlands Remaining Coastal Wetlands

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