Trees and forests as nature-based solutions in the US

Grant Domke, grant.m.domke@usda.gov
USDA Forest Service, Northern Research Station

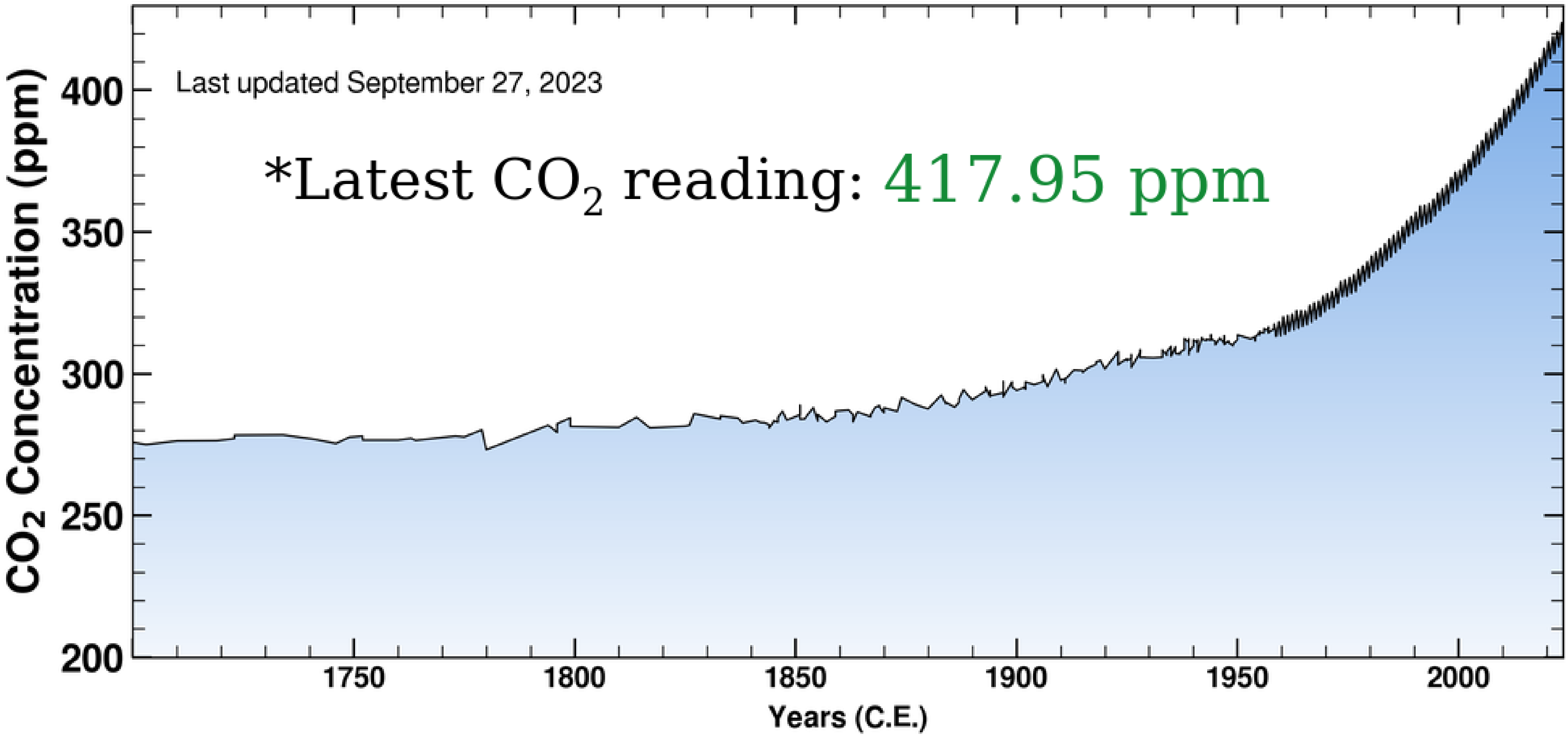
Photo credit: PNW FIA Field Crew

Forest Service cooperators: Brian Walters (NRS), Jim Smith (NRS), Jon Knott (NRS), Courtney Giebink (NRS), Chris Woodall (NRS), John Coulston (SRS), Sean Healey (RMRS), Andrew Gray (PNW), James Westfall (NRS), Chris Swanston (NRS), Chris Fettig (PSW), Greg Liknes (NRS), Andy Hudak (RMRS), among many others

University and Agency cooperators: Steve Ogle (CSU), Chris Edgar (UMN), Lucas Nave (MTU), Songlin Fei (Purdue U), Andy Finley (MSU), Sassan Saatchi (NASA JPL), Phil Radtke (VPI), Jeremy Lichstein (UFlorida), among many others

MSU FCCP Forests + Climate Learning Exchange Series – 4 October 2023

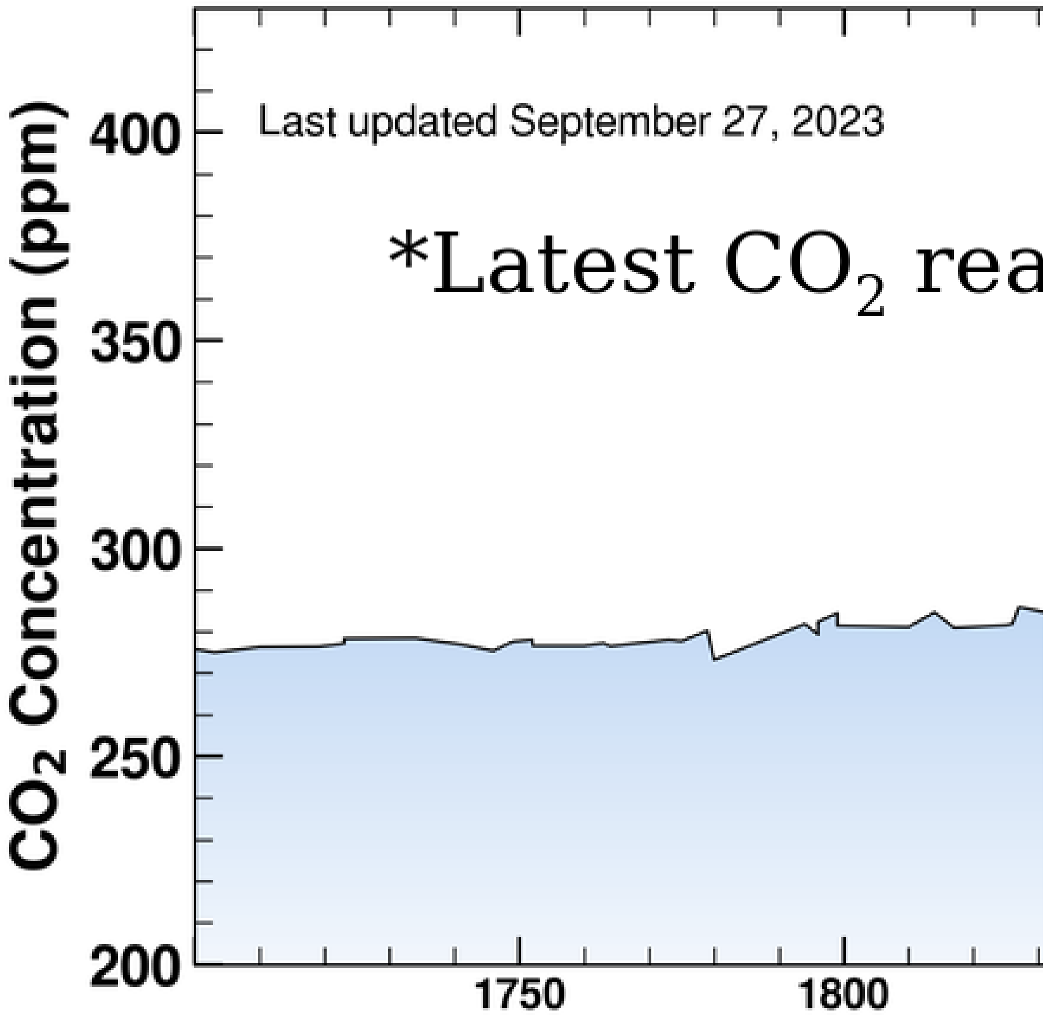
Why is this important?

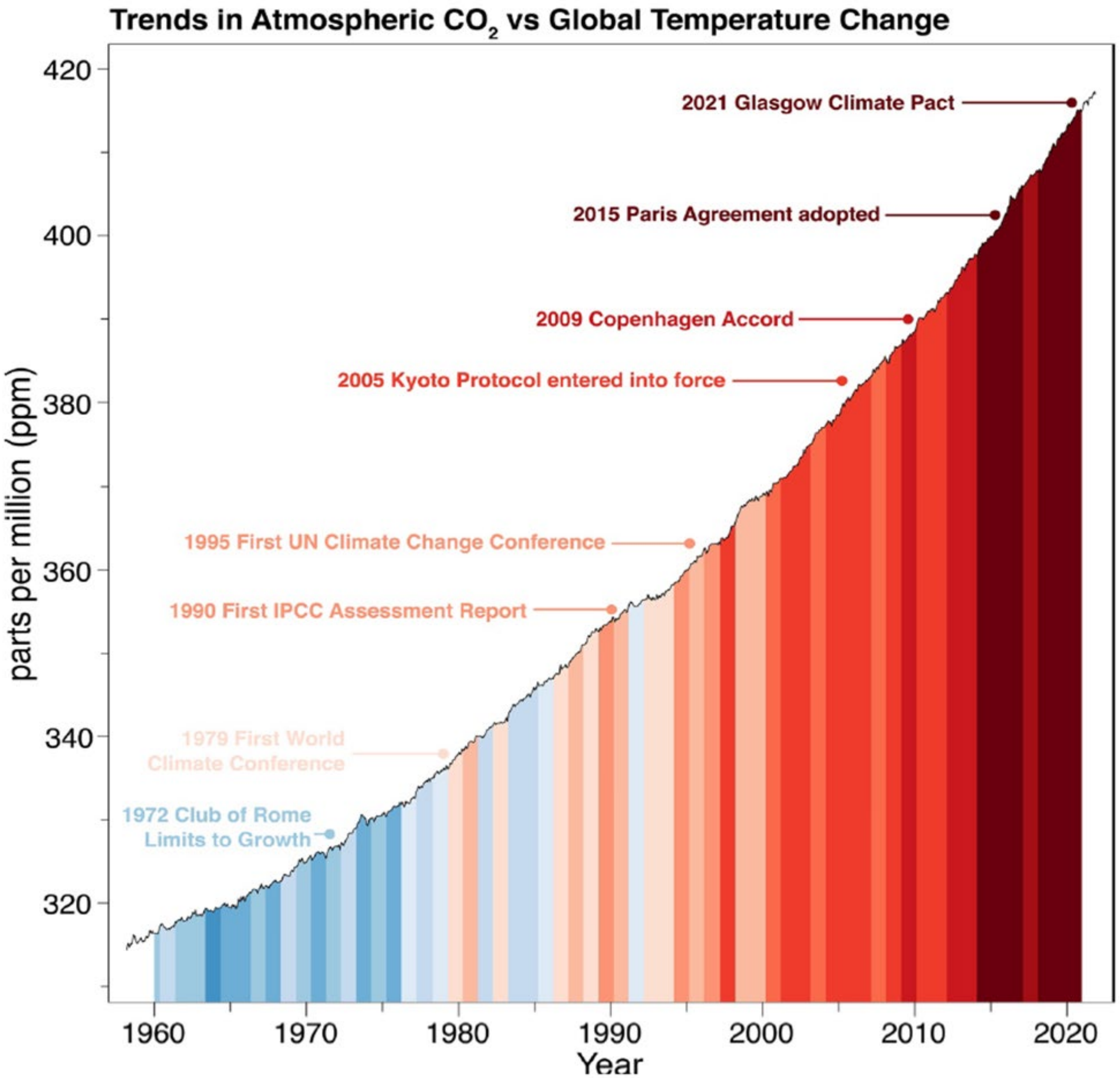


Maslin, M. et al. 2022. A short history of the succession and failures of the international climate change negotiations. UCL Press. doi: 10.14324/111.444/000178.v2

C. D. Keeling, S. C. Piper, R. B. Bacastow, M. Wahlen, T. P. Whorf, M. Heimann, and H. A. Meijer, Exchanges of atmospheric CO2 and 13CO2 with the terrestrial biosphere and oceans from 1978 to 2000. I. Global aspects, SIO Reference Series, No. 01-06, Scripps Institution of Oceanography, San Diego, 88 pages, 2001. http://escholarship.org/uc/item/09v319r9

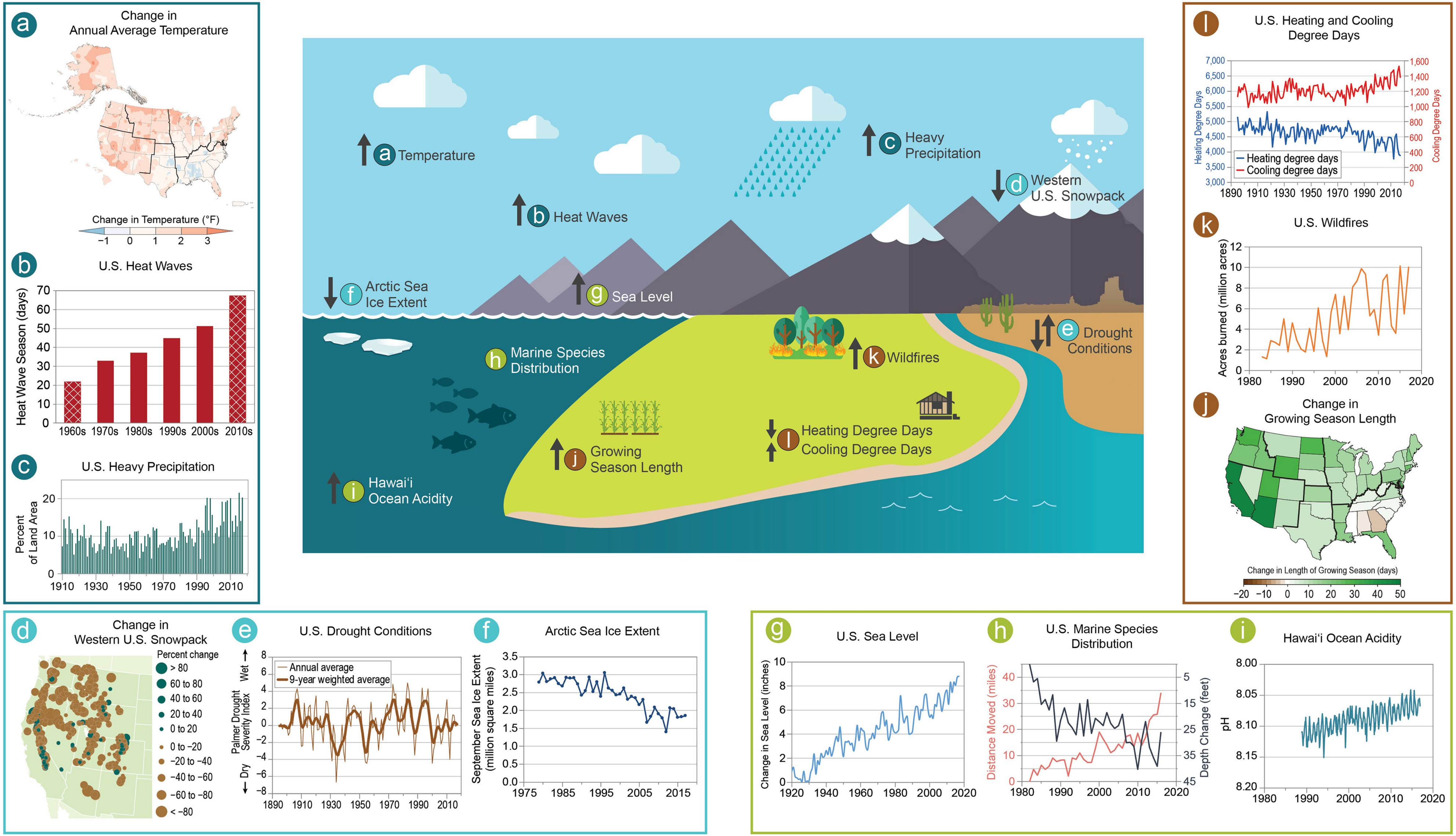
Why is this important?





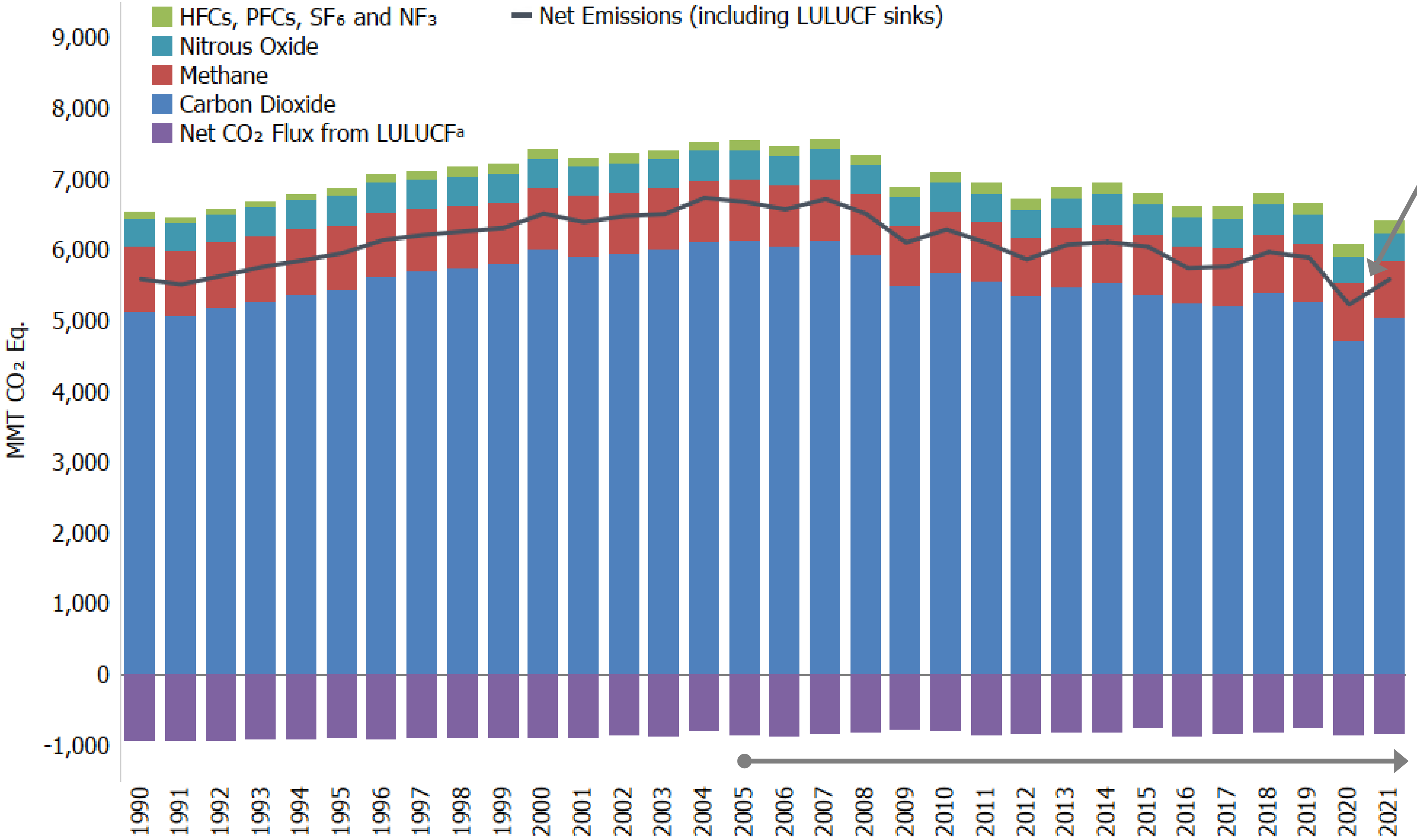
Maslin, M. et al. 2022. A short history of the succession and failures of the international climate change negotiations. UCL Press. doi: 10.14324/111.444/000178.v2

C. D. Keeling, S. C. Piper, R. B. Bacastow, M. Wahlen, T. P. Whorf, M. Heimann, and H. A. Meijer, Exchanges of atmospheric CO2 and 13CO2 with the terrestrial biosphere and oceans from 1978 to 2000. I. Global aspects, SIO Reference Series, No. 01-06, Scripps Institution of Oceanography, San Diego, 88 pages, 2001. http://escholarship.org/uc/item/09v319r9



Jay, A., et al. 2018: Overview. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 33–71. doi: 10.7930/NCA4.2018.***CH 1***

U.S. GHG emissions by gas, 1990-2021

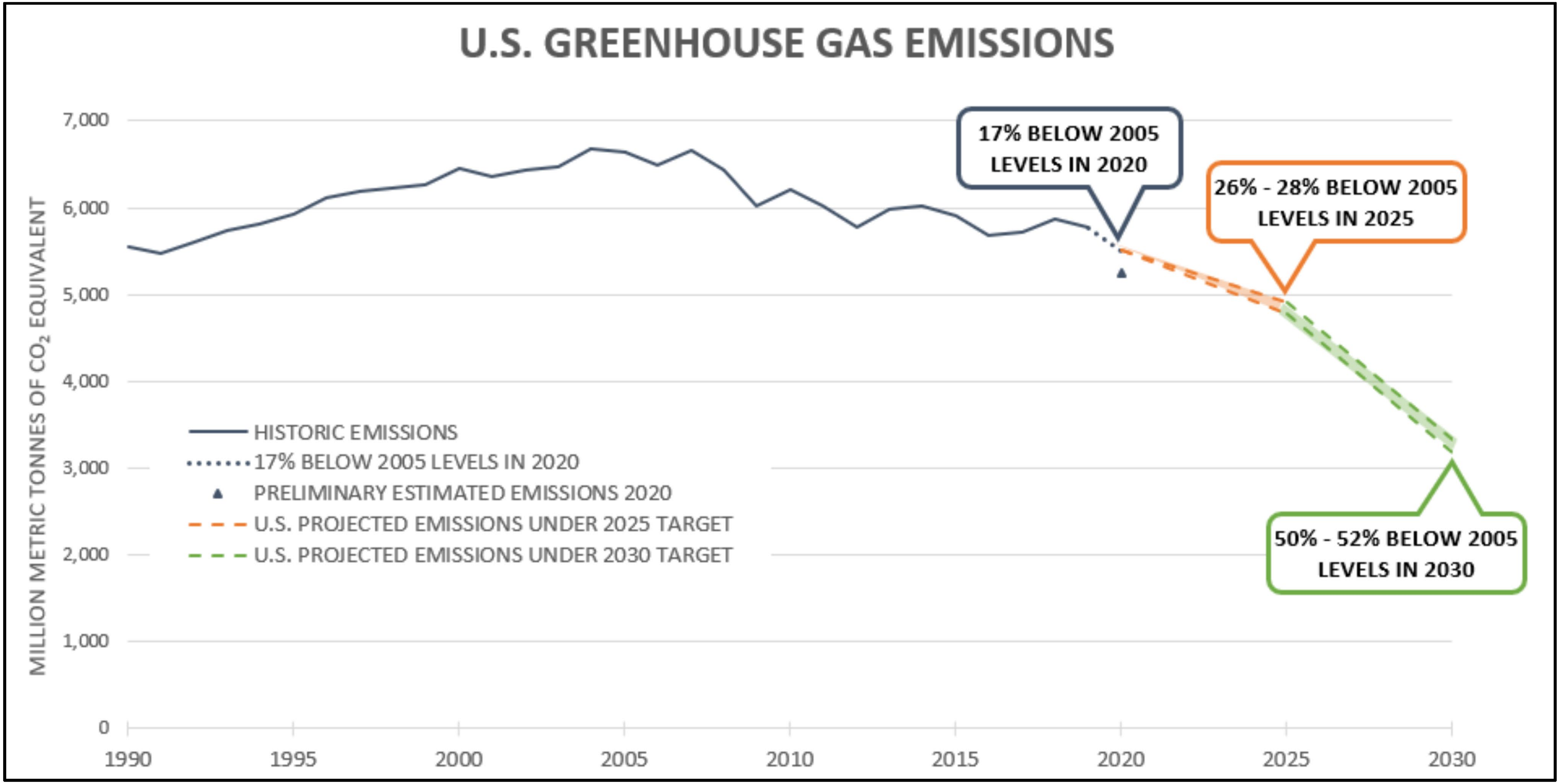


In 2021, net emissions (accounting for sequestration from land sector) increased 6.8% from 2020 levels
(see black line)

Net Emissions decreased ~16% from 2005 to 2021
(see black line)

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

Relevance to recent US commitments



https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/United%20States%20of%20America%20First/United%20States%20NDC%20April%2021%202021%20Final.pdf

What are nature-based solutions?

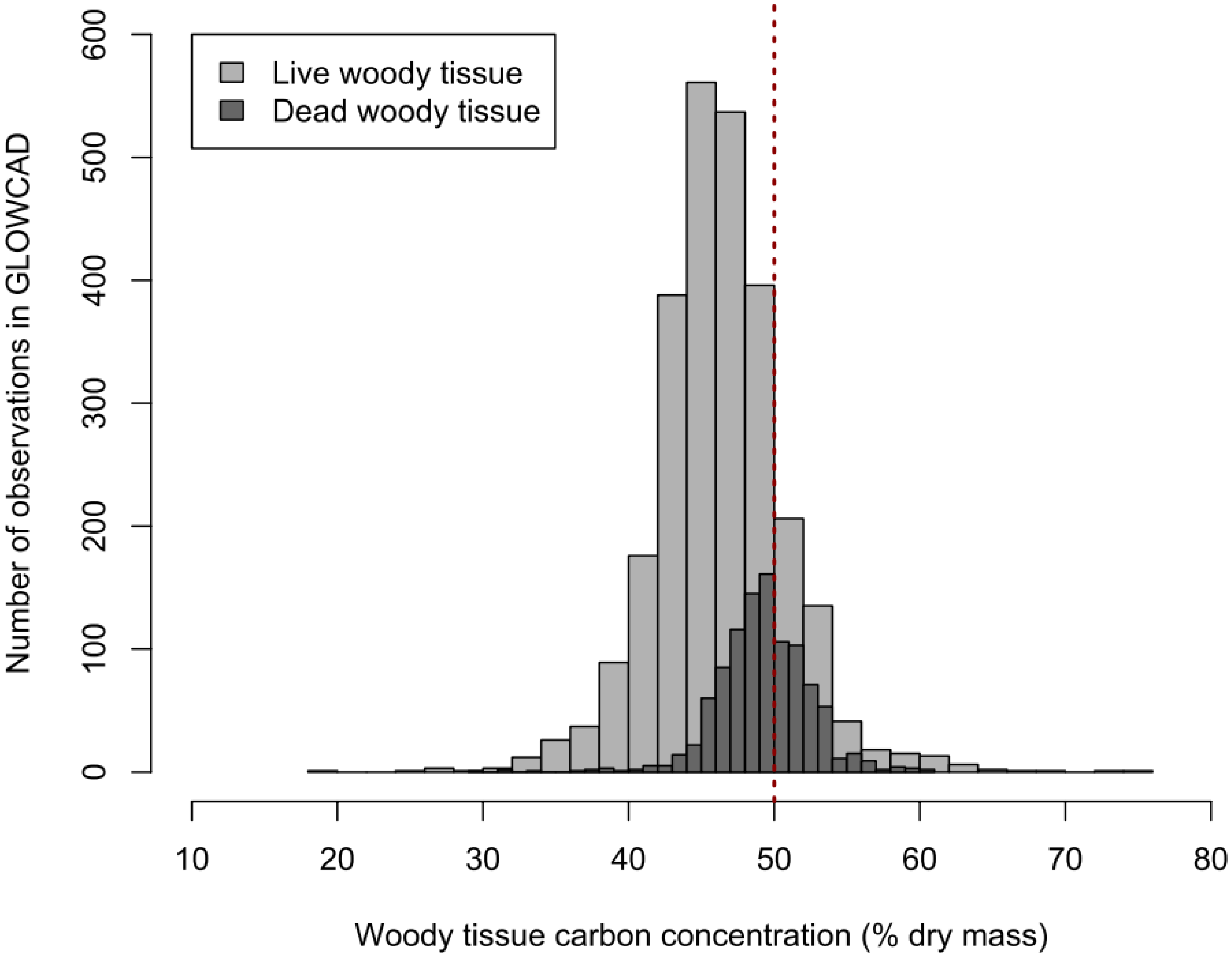
"Actions to **protect**, sustainably **manage** and **restore** natural and modified **ecosystems** in ways **that address societal challenges** effectively and adaptively, to provide both human well-being and biodiversity benefits. They are underpinned by benefits that flow from healthy ecosystems and target major challenges like **climate change**, **disaster risk reduction, food and water security, health** and are critical to **economic development**."

What are nature-based solutions?

Source	Mitigation objective (max °C)	Cost constraints	2030 mitigation potential $GtCO_2e$/year*				2050 mitigation potential $GtCO_2e$/year*				2020-2050 mitigation potential $GtCO_2e$*			
			Protect	Manage	Restore	All	Protect	Manage	Restore	All	Protect	Manage	Restore	All
Griscom *et al.* 2017	2	<US$ 100/tCO2e	3.9	3.8	3.6	11.3	3.9	3.8	3.6	11.3	-	-	-	288.2
Roe *et al.* 2019	1.5	Mixed (max; <US$ 25/tCO2e; <US$ 100/tCO2e)	*3.4*	*>0.7†*	*>0.9†*	*>5.0*	*4.6*	*3.9*	*3.6*	*12.1*	-	-	-	
Girardin *et al.* 2021	1.5	<US$ 100/tCO2e until 2025; <US$ 200/tCO2e 2025-2055	-	-	-	11.7 (10 at 2025)	-	-	-	18.3 (20 at 2055)	-	-	-	380.0
	2	<US$ 100/tCO2e	3.9	4.3	2.0	10.1	3.9	4.3	2.0	10.1	-	-	-	280.0
McKinsey & Company 2021	-	Mixed (mainly land rents <US$ 45/ha)	3.8	0.8	2.1	6.7	-	-	-	-	-	-	-	-
Wilkiinson 2020	1.5	Mixed	-	-	-	-	-	-	-	*>18.5‡*	*54.3*	*334.7*	*164.7*	*553.7*
	2	Mixed	-	-	-	-	-	-	-	*>11‡*	*33.5*	*188.0*	*108*	*329.5*

CarbonBrief

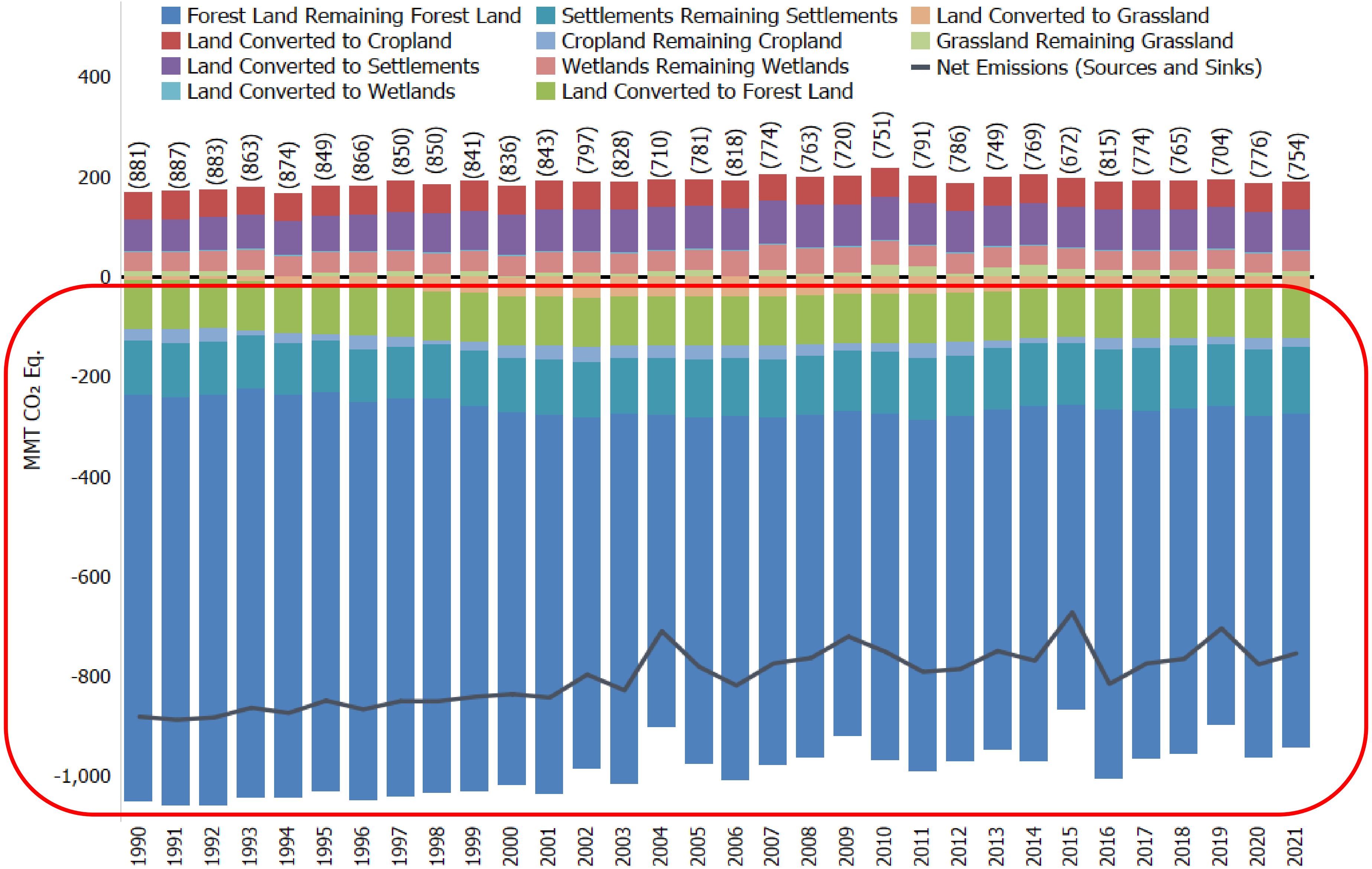
Trees and carbon



Doaisami, M., Kish, R., Paroshy, Domke, G.M., Thomas, S.C., Martin, A.R. 2022. A database of wood carbon fractions across the world's trees and forests. Nature – Scientific Data. https://www.nature.com/articles/s41597-022-01396-1

Emissions and removals from the LULUCF in the US

> 95%

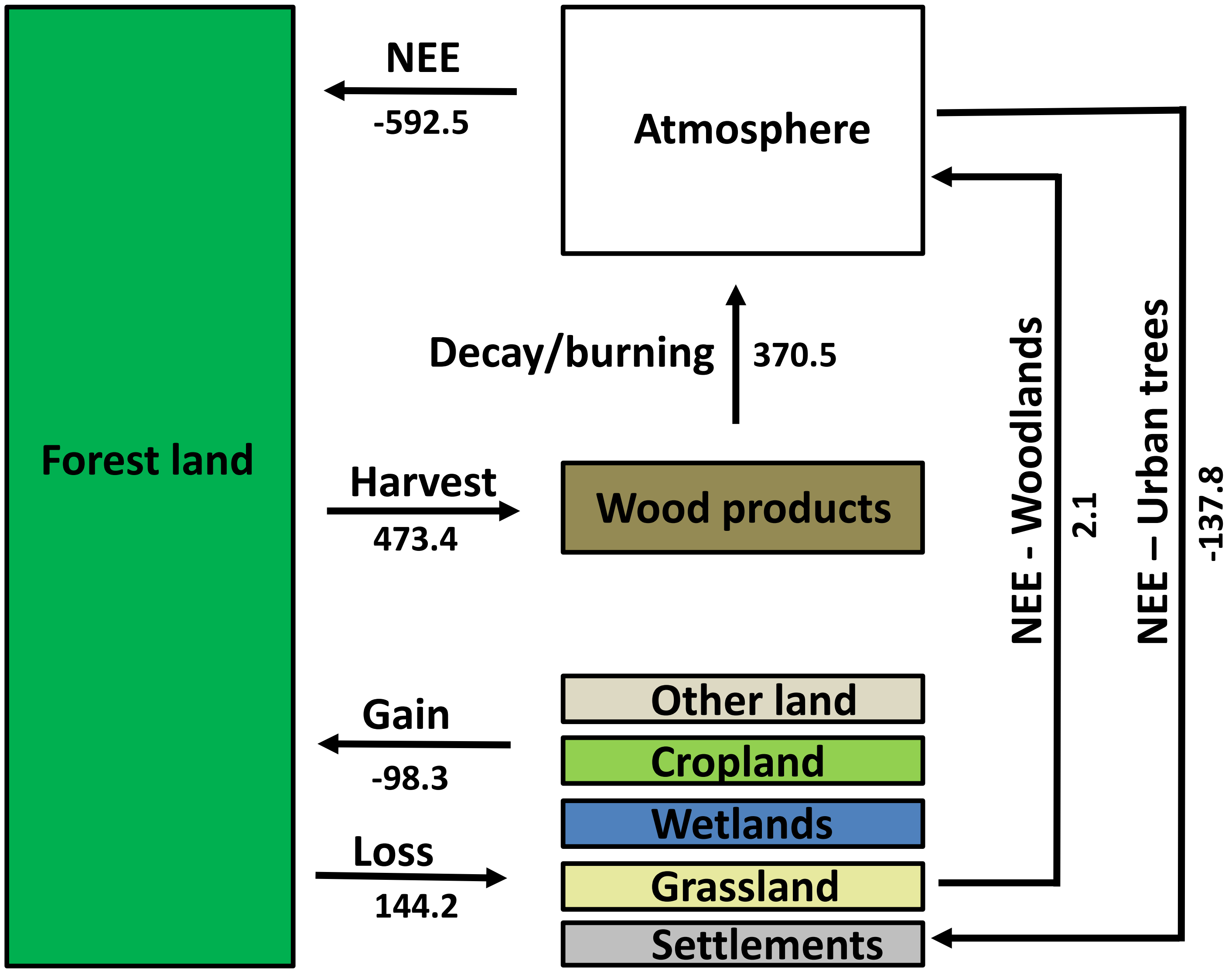


U.S. Environmental Protection Agency [U.S. EPA]. 2023. Inventory of U.S. greenhouse gas emissions and sinks: 1990–2021. EPA 430-R-23-002. Washington, DC: U.S. Environmental Protection Agency.
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021

Forest land carbon cycling (MMT CO_2 eq.), US 2021

-785.0

~13%



Domke, G.M. et al. 2023. Greenhouse gas emissions and removals from forest land, woodlands, urban trees, and harvested wood products in the United States, 1990–2021. Resource Bulletin WO-101. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Washington Office. 10 p. https://doi.org/10.2737/WO-RB-101.

This is equivalent to greenhouse gas emissions from:

105,143,990

174,686,269 gasoline-powered passenger vehicles driven for one year

2,012,385,815,503 miles driven by an average gasoline-powered passenger vehicle

This is equivalent to CO_2 emissions from:

88,331,270,395 gallons of gasoline consumed

77,111,984,283 gallons of diesel consumed

879,320,448,178 pounds of coal burned

10,391,914 tanker trucks' worth of gasoline

98,936,391 homes' energy use for one year

152,741,032 homes' electricity use for one year

4,327,867 railcars' worth of coal burned

1,815,653,011 barrels of oil consumed

36,062,173,134 propane cylinders used for home barbeques

210 coal-fired power plants in one year

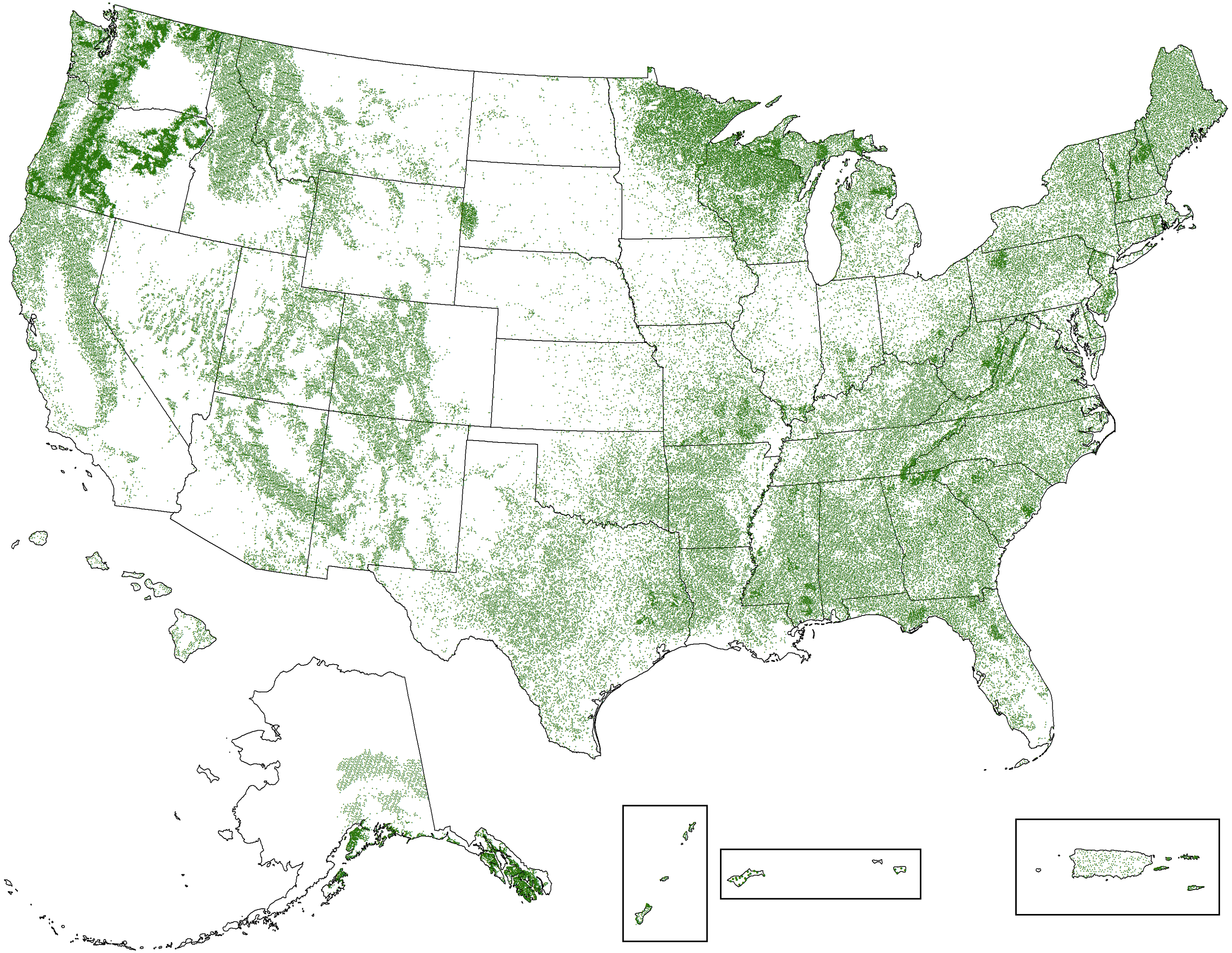
https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Brief overview of FIA

- Specifically designed to track change over time
  - Permanent sample plots across all lands and ownerships
  - Remeasurement every 5-10 years
- Multiple approaches for assessing disturbance (e.g., disturbance code), and tree- and site-level attributes (e.g., damage, mortality, removals)
- Observed land cover and land use attributes
- Publicly available and accessible in several formats
- It is not a carbon or greenhouse gas monitoring system

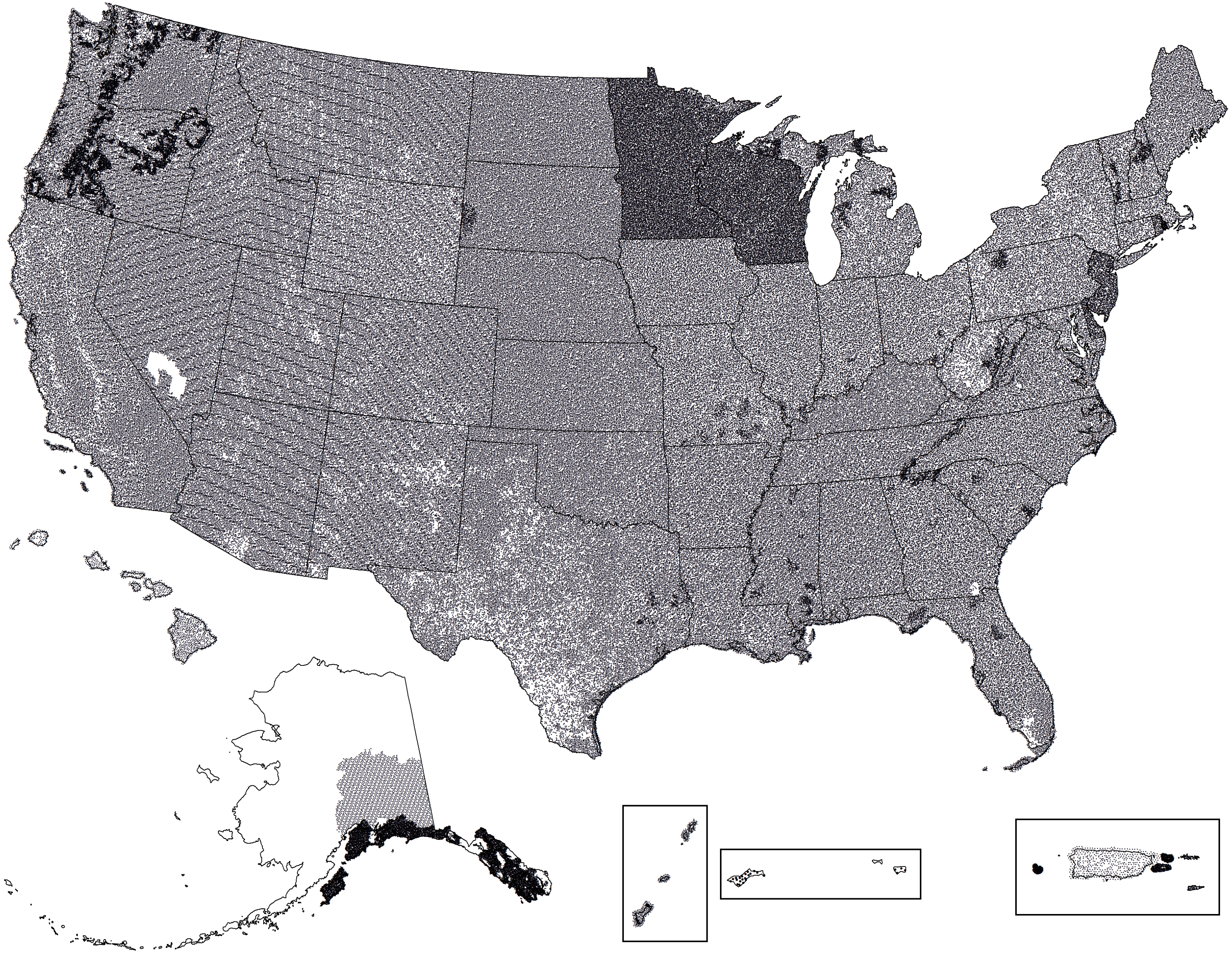
Bechtold W.A. and Patterson, P.J. 2005. The enhanced Forest Inventory and Analysis program—national sampling design and estimation procedures. Gen. Tech. Rep. SRS-80. 85 p.

Brief overview of FIA – distribution of plots



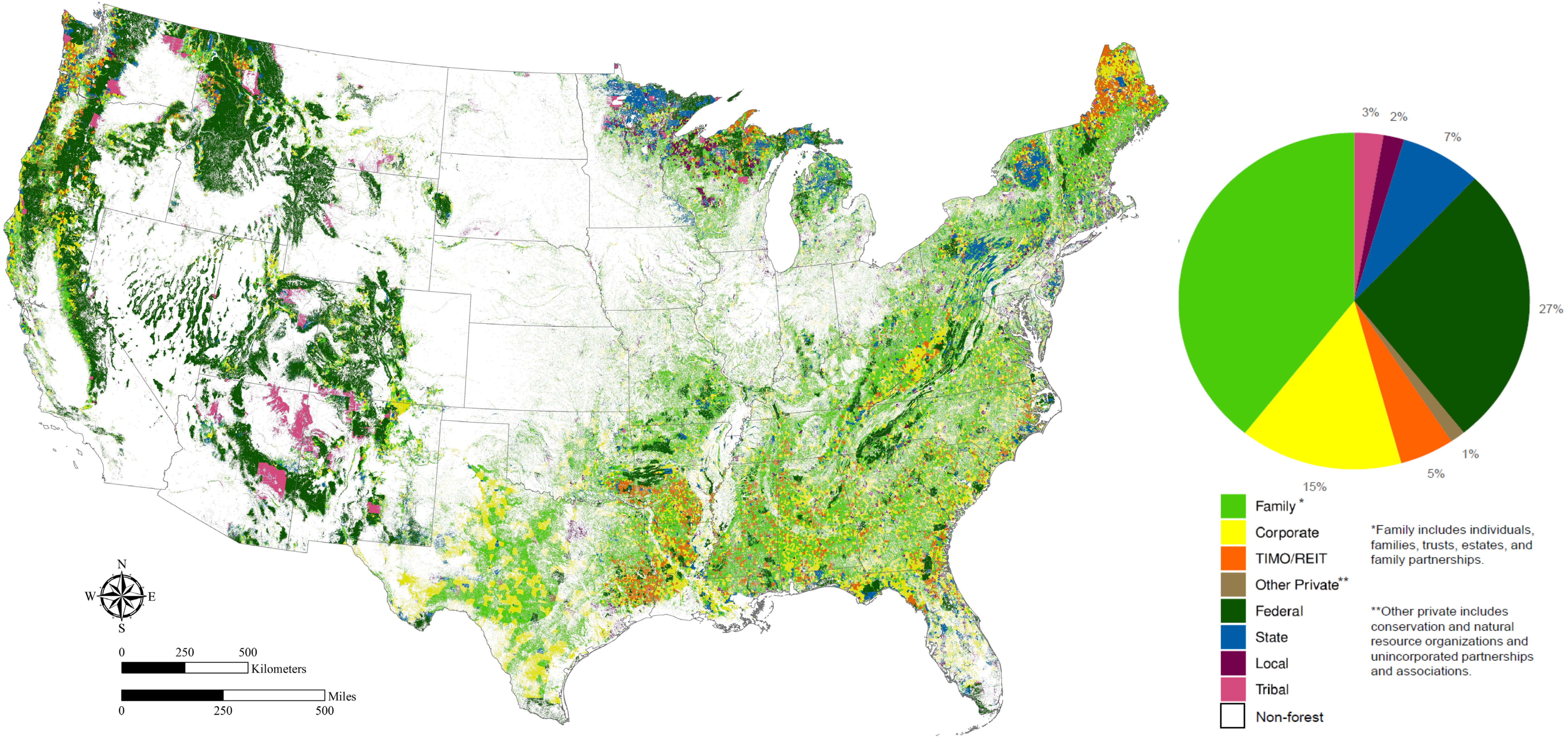
141,588

Brief overview of FIA – distribution of plots



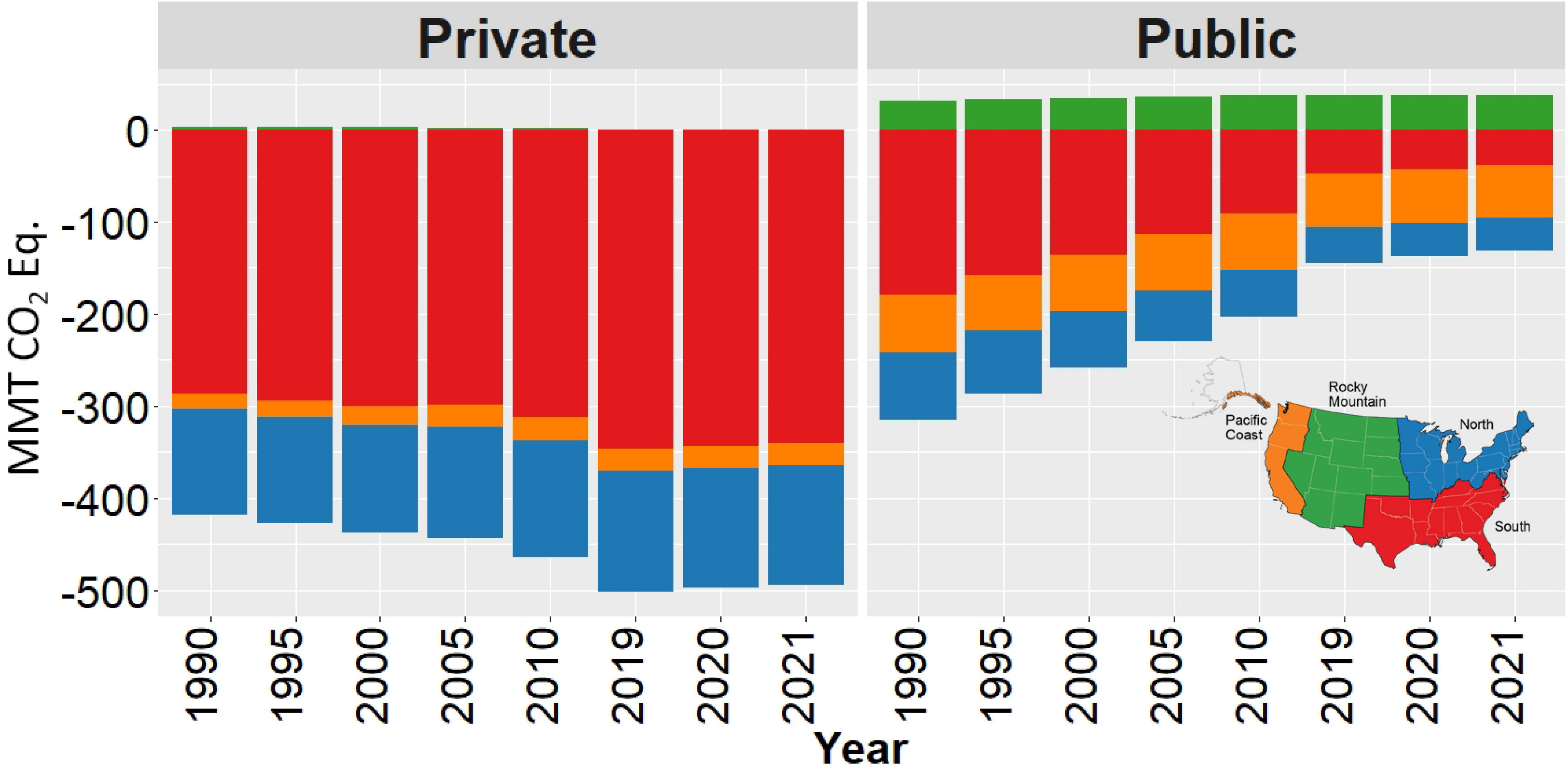
350,140

Where is the forest in the US and who owns it?



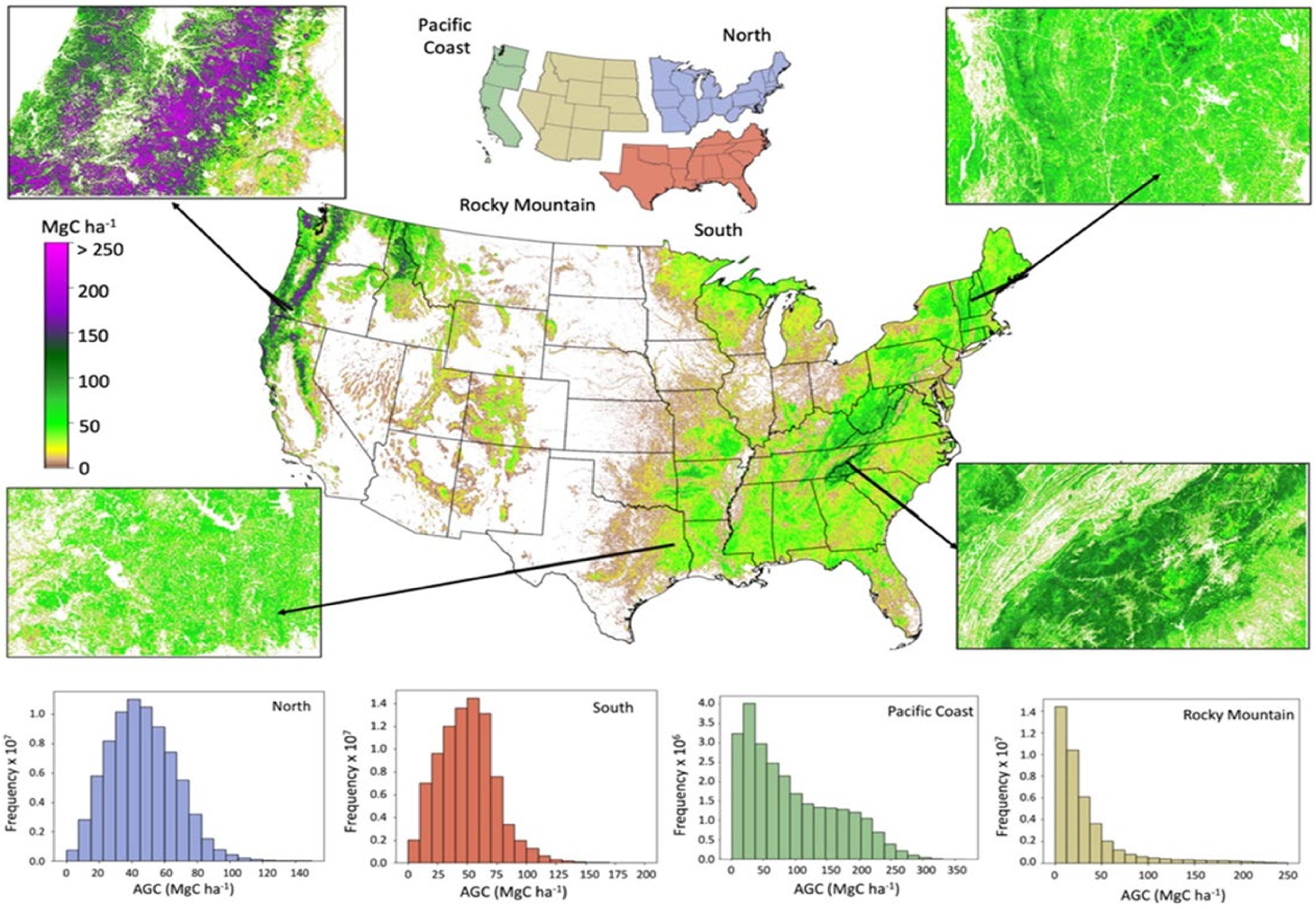
Sass, Emma M.; Butler, Brett J.; Markowski-Lindsay, Marla. 2020. Distribution of forest ownerships across the conterminous United States, 2017. Res. Map NRS-11. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. https://doi.org/10.2737/NRS-RMAP-11

Forest land carbon stock changes by ownership



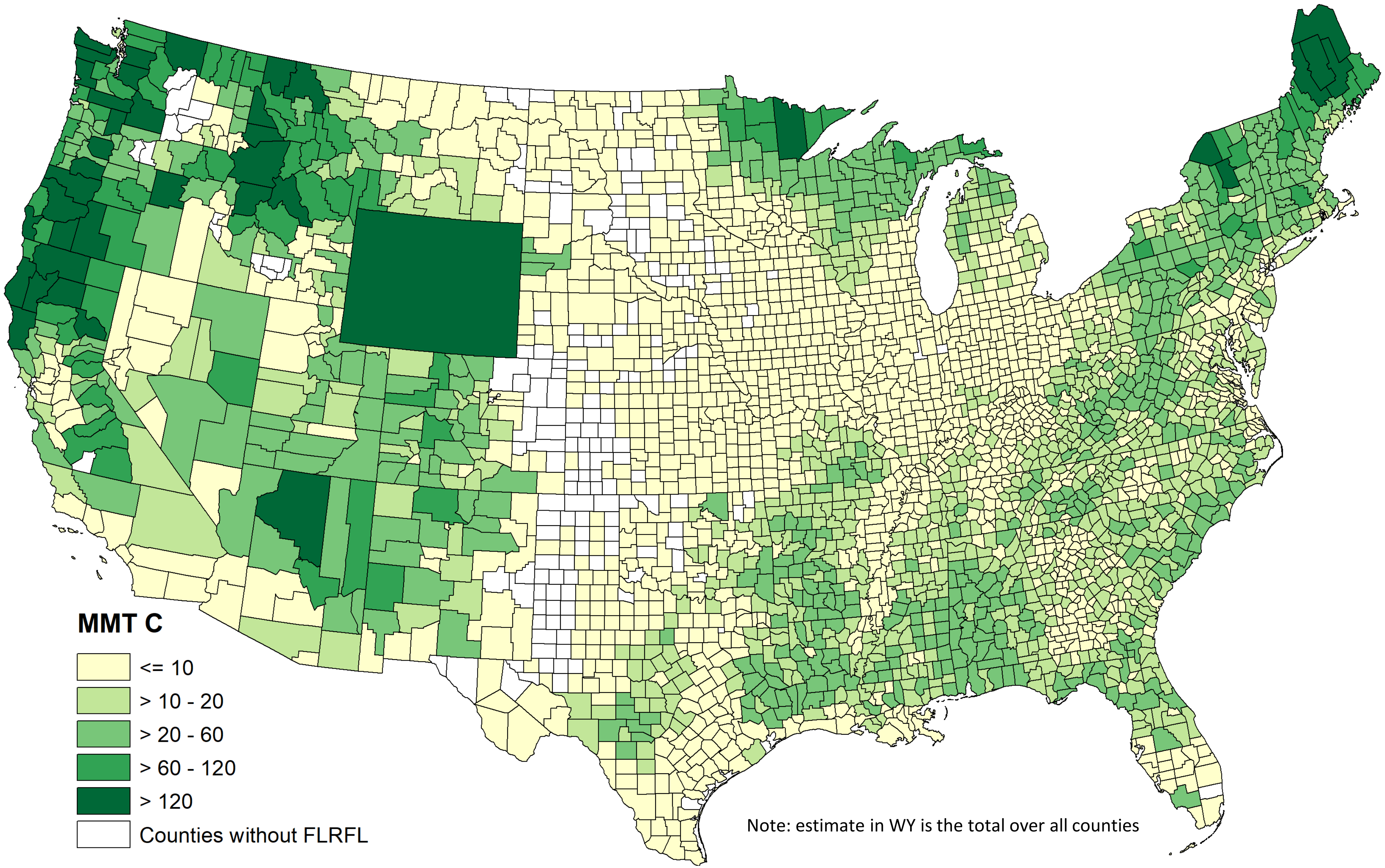
Domke, G.M. et al. 2023. Greenhouse gas emissions and removals from forest land, woodlands, urban trees, and harvested wood products in the United States, 1990–2021. Resource Bulletin WO-101. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Washington Office. 10 p. https://doi.org/10.2737/WO-RB-101.

Where is the carbon in trees in the CONUS?



Yu, Y., Saatchi, S., Domke, G.M., Walters, B., Woodall, C., Ganguly, S., Li, S., Kalia, S., Park, T., Nemani, R. and Hagen, S.C., 2022. Making the US national forest inventory spatially contiguous and temporally consistent. Environmental Research Letters, 17(6), p.065002. https://iopscience.iop.org/article/10.1088/1748-9326/ac6b47

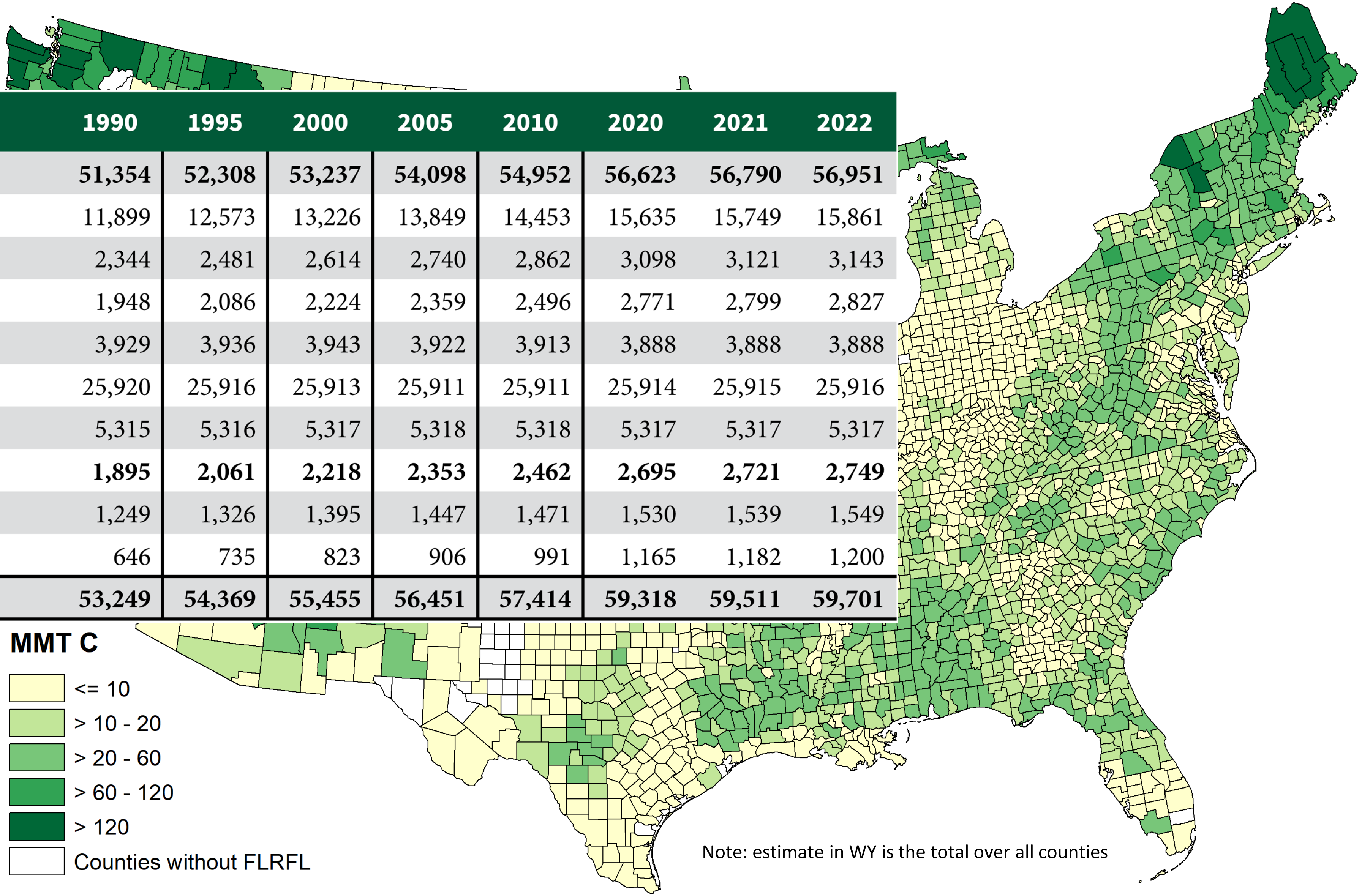
Where is the carbon in forest land (MMT C)?



Domke, G.M. et al. 2023. Greenhouse gas emissions and removals from forest land, woodlands, urban trees, and harvested wood products in the United States, 1990–2021. Resource Bulletin WO-101. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Washington Office. 10 p. https://doi.org/10.2737/WO-RB-101.

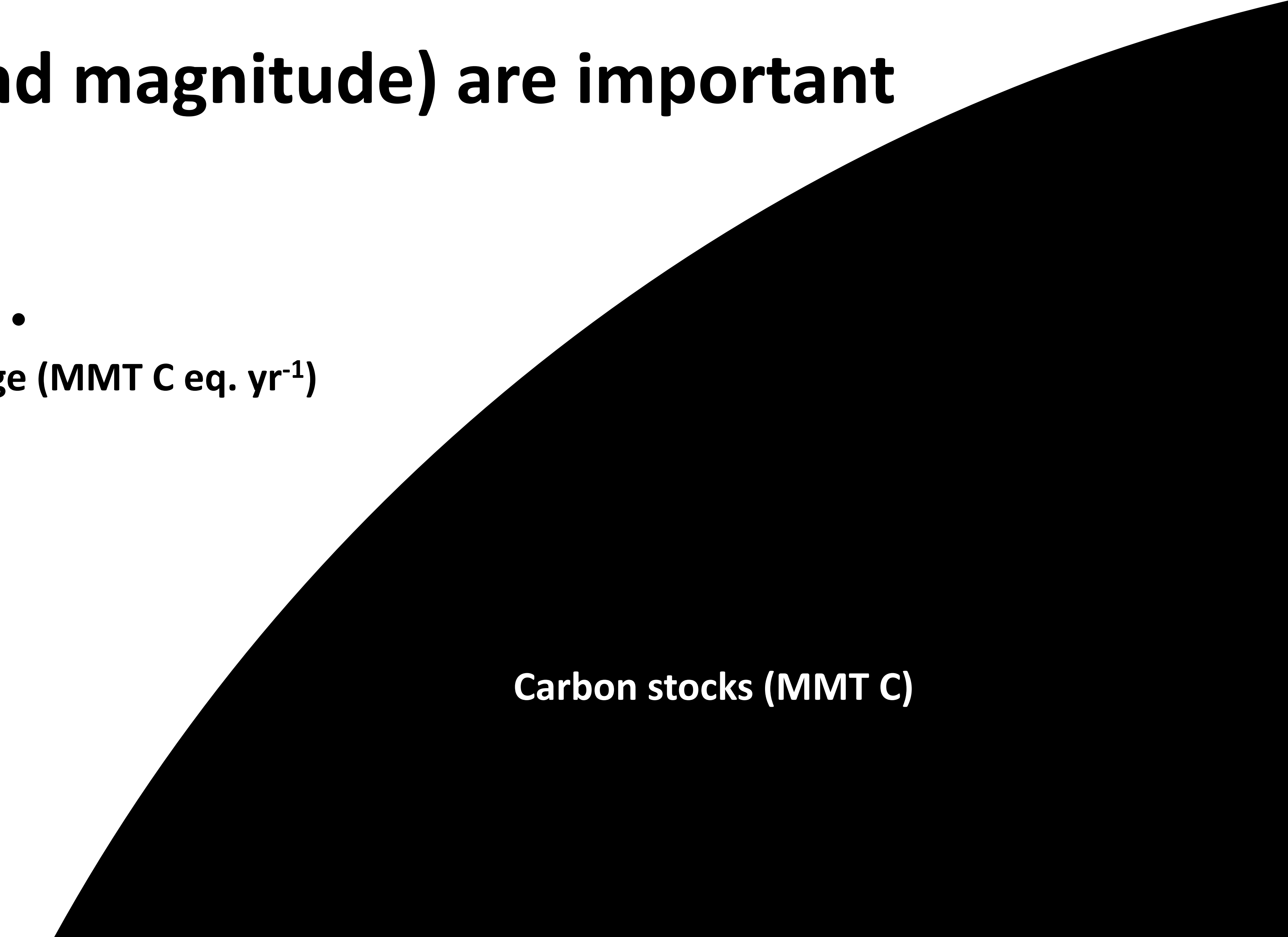
Where is the carbon in forest land (MMT C)?

Carbon pool[a]	1990	1995	2000	2005	2010	2020	2021	2022
Forest	**51,354**	**52,308**	**53,237**	**54,098**	**54,952**	**56,623**	**56,790**	**56,951**
Aboveground biomass	11,899	12,573	13,226	13,849	14,453	15,635	15,749	15,861
Belowground biomass	2,344	2,481	2,614	2,740	2,862	3,098	3,121	3,143
Dead wood	1,948	2,086	2,224	2,359	2,496	2,771	2,799	2,827
Litter	3,929	3,936	3,943	3,922	3,913	3,888	3,888	3,888
Soil (mineral)	25,920	25,916	25,913	25,911	25,911	25,914	25,915	25,916
Soil (organic)	5,315	5,316	5,317	5,318	5,318	5,317	5,317	5,317
Harvested wood	**1,895**	**2,061**	**2,218**	**2,353**	**2,462**	**2,695**	**2,721**	**2,749**
Products in use	1,249	1,326	1,395	1,447	1,471	1,530	1,539	1,549
Solid waste disposal sites	646	735	823	906	991	1,165	1,182	1,200
Total stocks	**53,249**	**54,369**	**55,455**	**56,451**	**57,414**	**59,318**	**59,511**	**59,701**

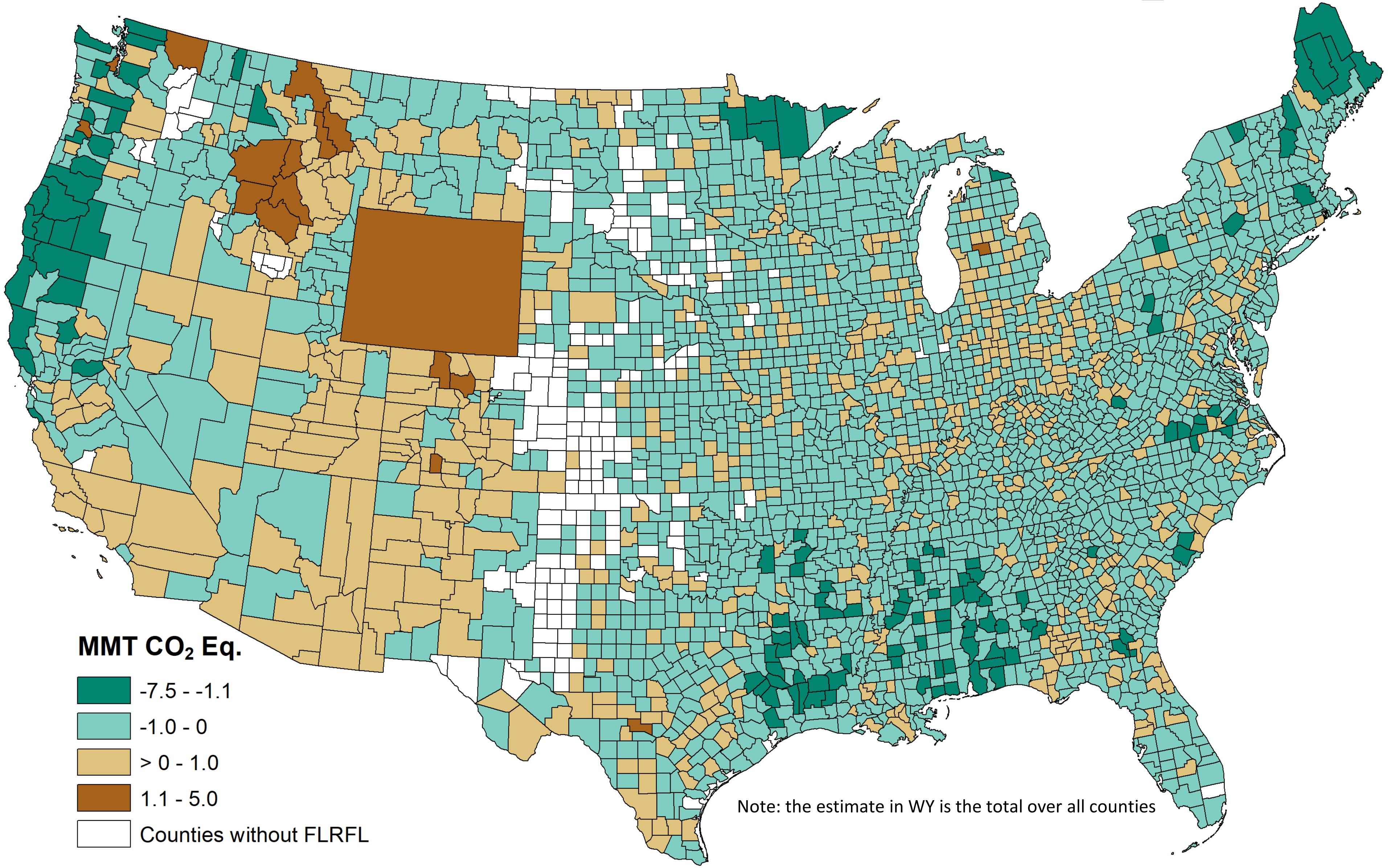


Domke, G.M. et al. 2023. Greenhouse gas emissions and removals from forest land, woodlands, urban trees, and harvested wood products in the United States, 1990–2021. Resource Bulletin WO-101. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Washington Office. 10 p. https://doi.org/10.2737/WO-RB-101.

Context (and magnitude) are important

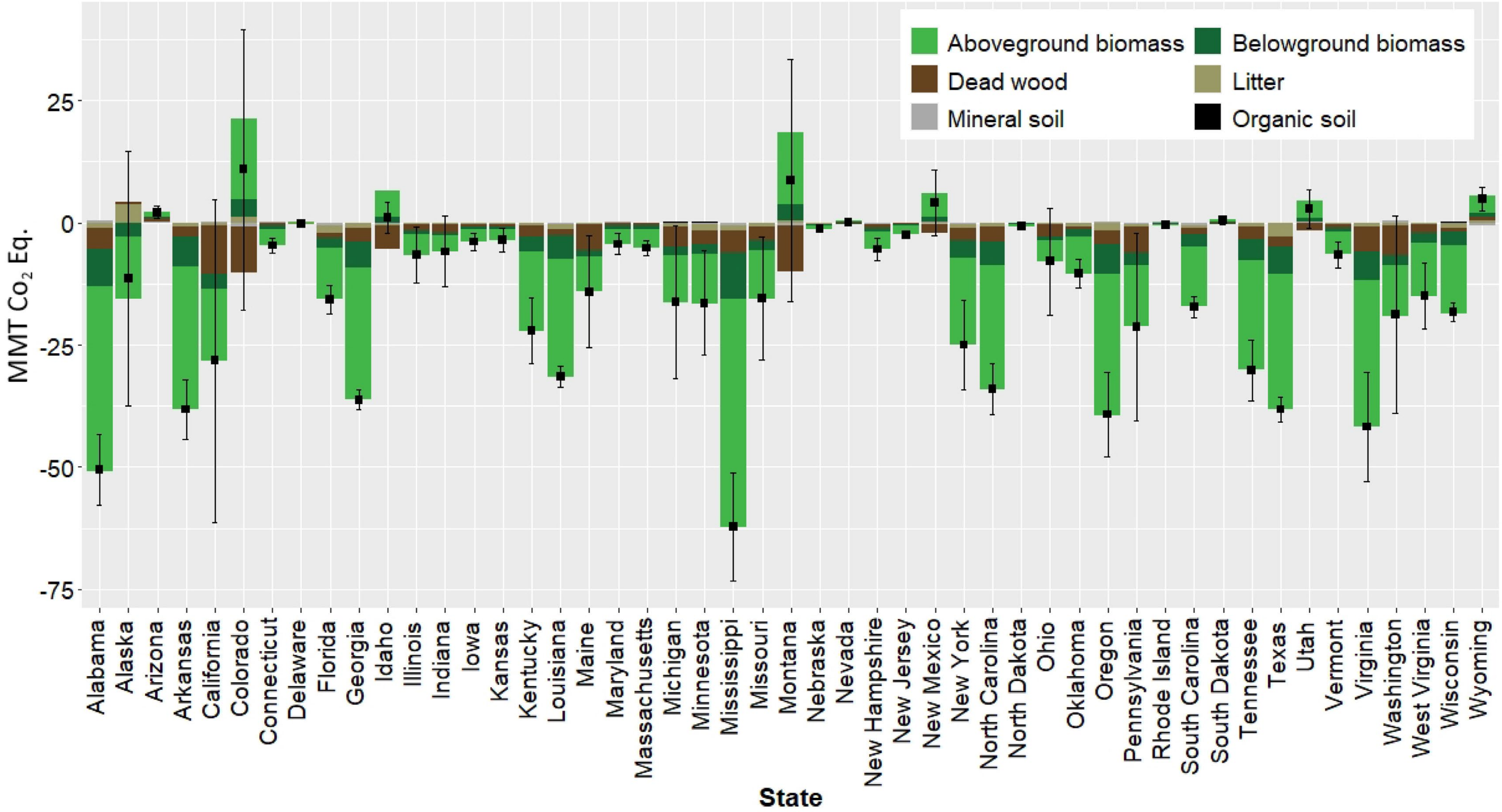


How are carbon stocks changing (MMT CO_2 eq.)?



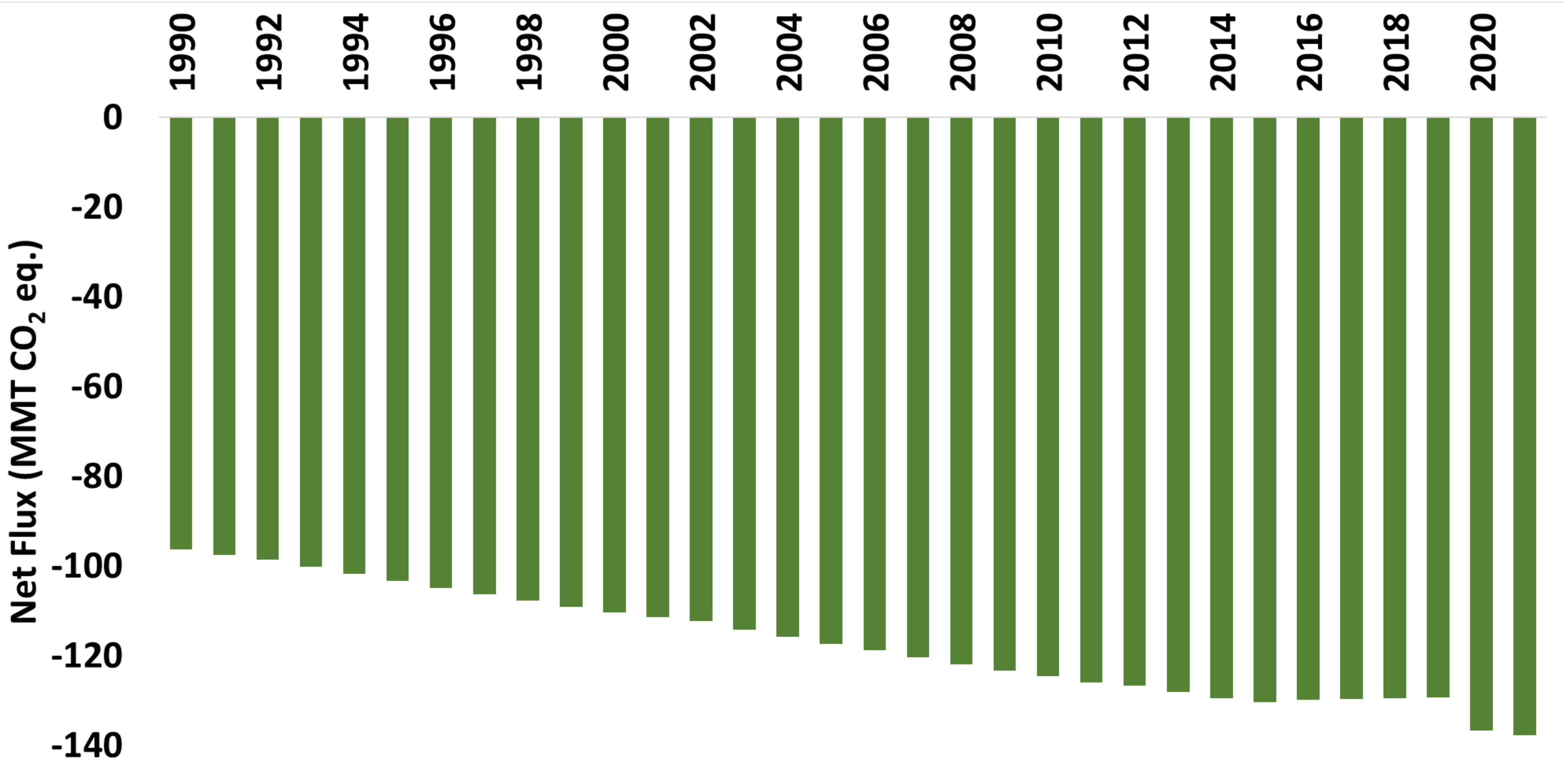
Domke, G.M. et al. 2023. Greenhouse gas emissions and removals from forest land, woodlands, urban trees, and harvested wood products in the United States, 1990–2021. Resource Bulletin WO-101. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Washington Office. 10 p. https://doi.org/10.2737/WO-RB-101.

How are carbon stocks changing (MMT CO_2 eq.)?



Domke, G.M. et al. 2023. Greenhouse gas emissions and removals from forest land, woodlands, urban trees, and harvested wood products in the United States, 1990–2021. Resource Bulletin WO-101. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Washington Office. 10 p. https://doi.org/10.2737/WO-RB-101.

Trees in Settlements > 17% of the land sink



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

This is equivalent to greenhouse gas emissions from:

30,663,372	gasoline-powered passenger vehicles driven for one year
353,242,044,834	miles driven by an average gasoline-powered passenger vehicle

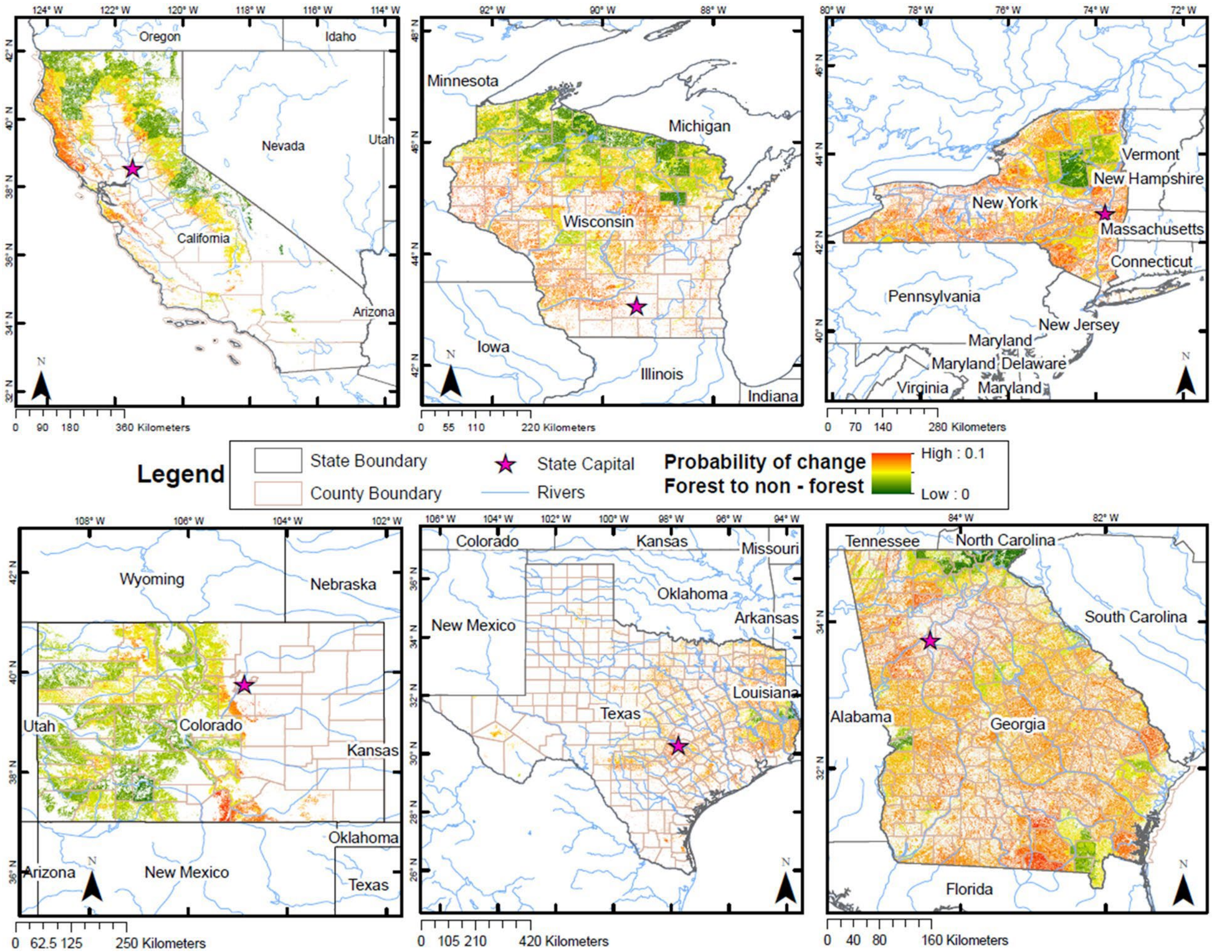
> 25% of passenger vehicle emissions each year

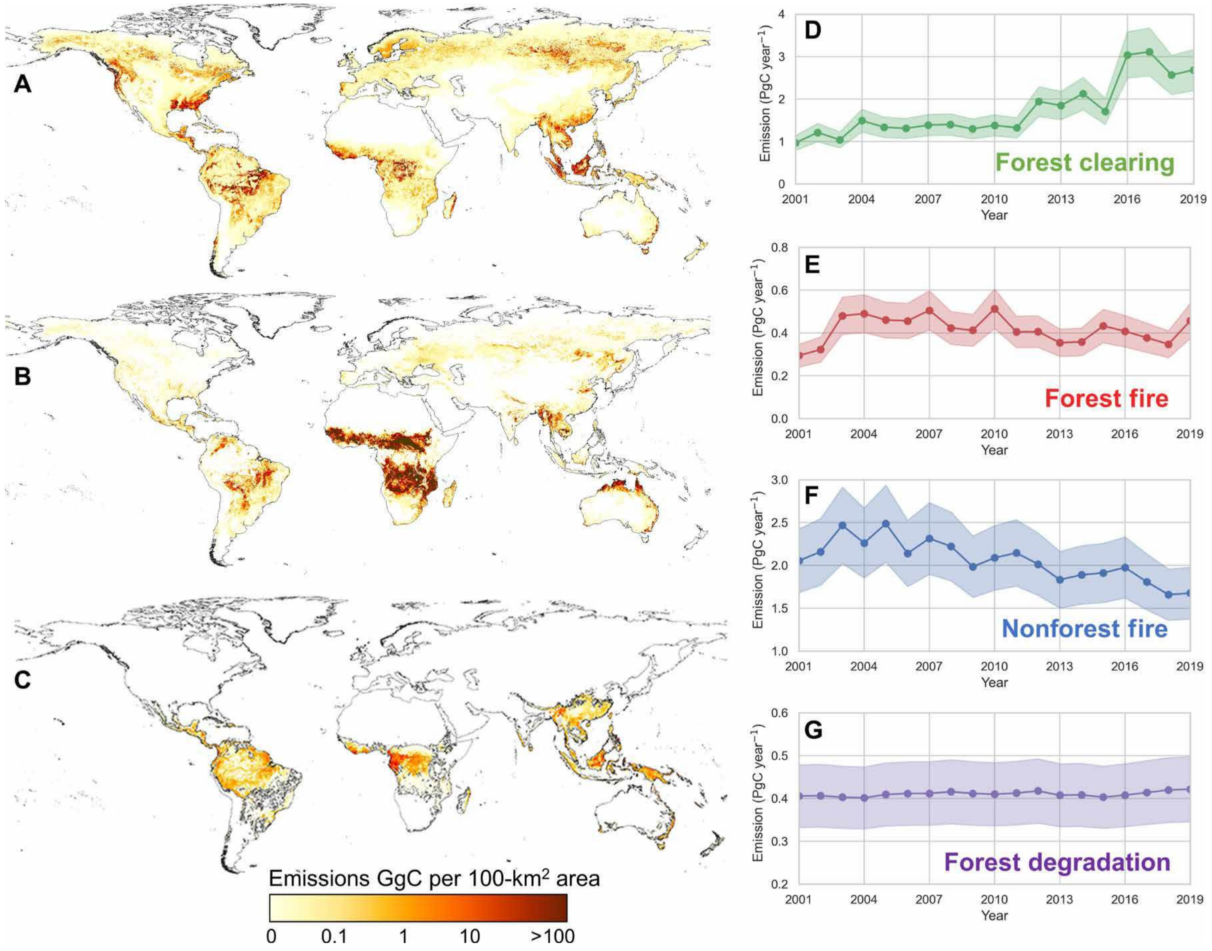
This is equivalent to CO_2 emissions from:

15,505,137,403	gallons of gasoline consumed
13,535,771,719	gallons of diesel consumed
154,350,597,577	pounds of coal burned
1,824,134	tanker trucks' worth of gasoline
17,366,696	homes' energy use for one year
26,811,238	homes' electricity use for one year
759,688	railcars' worth of coal burned
318,708,757	barrels of oil consumed
6,330,135,942	propane cylinders used for home barbeques
36.9	coal-fired power plants in one year
346	natural gas-fired power plants in one year
16,761,645,792,110	number of smartphones charged

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

What is contributing to changes in forest carbon?





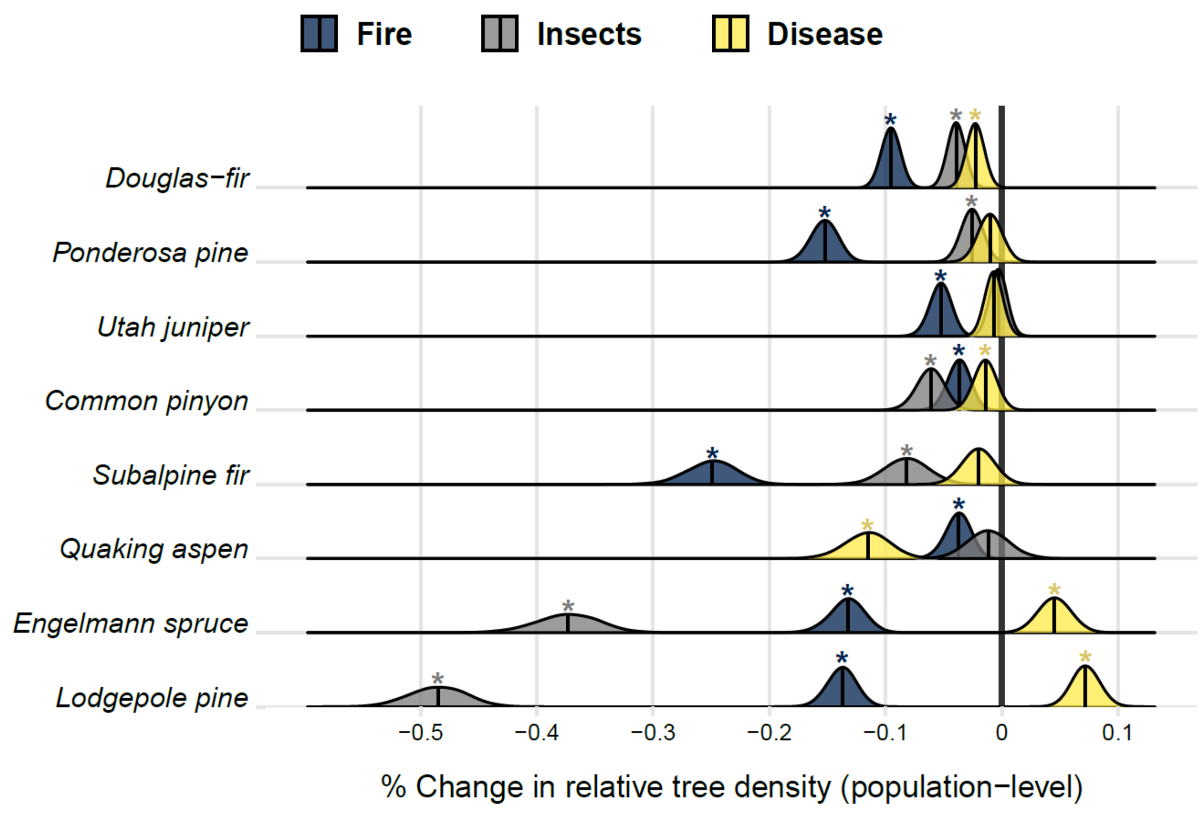
Quirion, Brendan R.; Domke, Grant M.; Walters, Brian F.; Lovett, Gary M.; Fargione, Joseph E.; Greenwood, Leigh; Serbesoff-King, Kristina; Randall, John M.; Fei, Songlin. 2021. Insect and Disease Disturbances Correlate With Reduced Carbon Sequestration in Forests of the Contiguous United States. Frontiers in Forests and Global Change. 4: 716582. 10 p. https://doi.org/10.3389/ffgc.2021.716582.

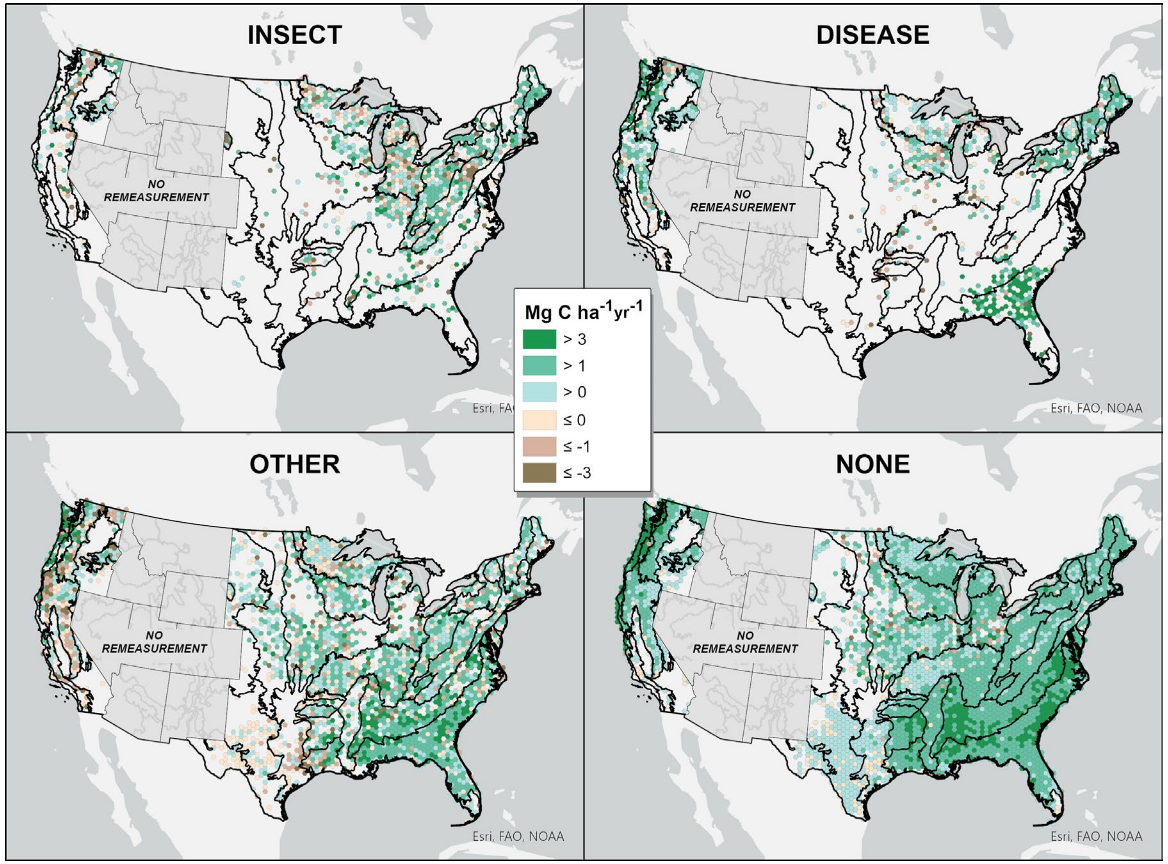
Stanke, Hunter; Finley, Andrew O.; Domke, Grant M.; Weed, Aaron S.; MacFarlane, David W. 2021. Over half of western United States' most abundant tree species in decline. Nature Communications. 12(1): 395-. https://doi.org/10.1038/s41467-020-20678-z.

Fitts, Lucia A.; Russell, Matthew B.; Domke, Grant M.; Knight, Joseph K. 2021. Modeling land use change and forest carbon stock changes in temperate forests in the United States. Carbon Balance and Management. 16(1): 4. 16 p. https://doi.org/10.1186/s13021-021-00183-6.

Xu, Liang; Saatchi, Sassan S.; Yang, Yan; Yu, Yifan; Pongratz, Julia; Bloom, A. Anthony; Bowman, Kevin; Worden, John; Liu, Junjie; Yin, Yi; Domke, Grant; McRoberts, Ronald E.; Woodall, Christopher; Nabuurs, Gert-Jan; de-Miguel, Sergio; Keller, Michael; Harris, Nancy; Maxwell, Sean; Schimel, David. 2021. Changes in global terrestrial live biomass over the 21st century. Science Advances. 7(27): eabe9829. 18 p. https://doi.org/10.1126/sciadv.abe9829.

What is contributing to changes in forest carbon?





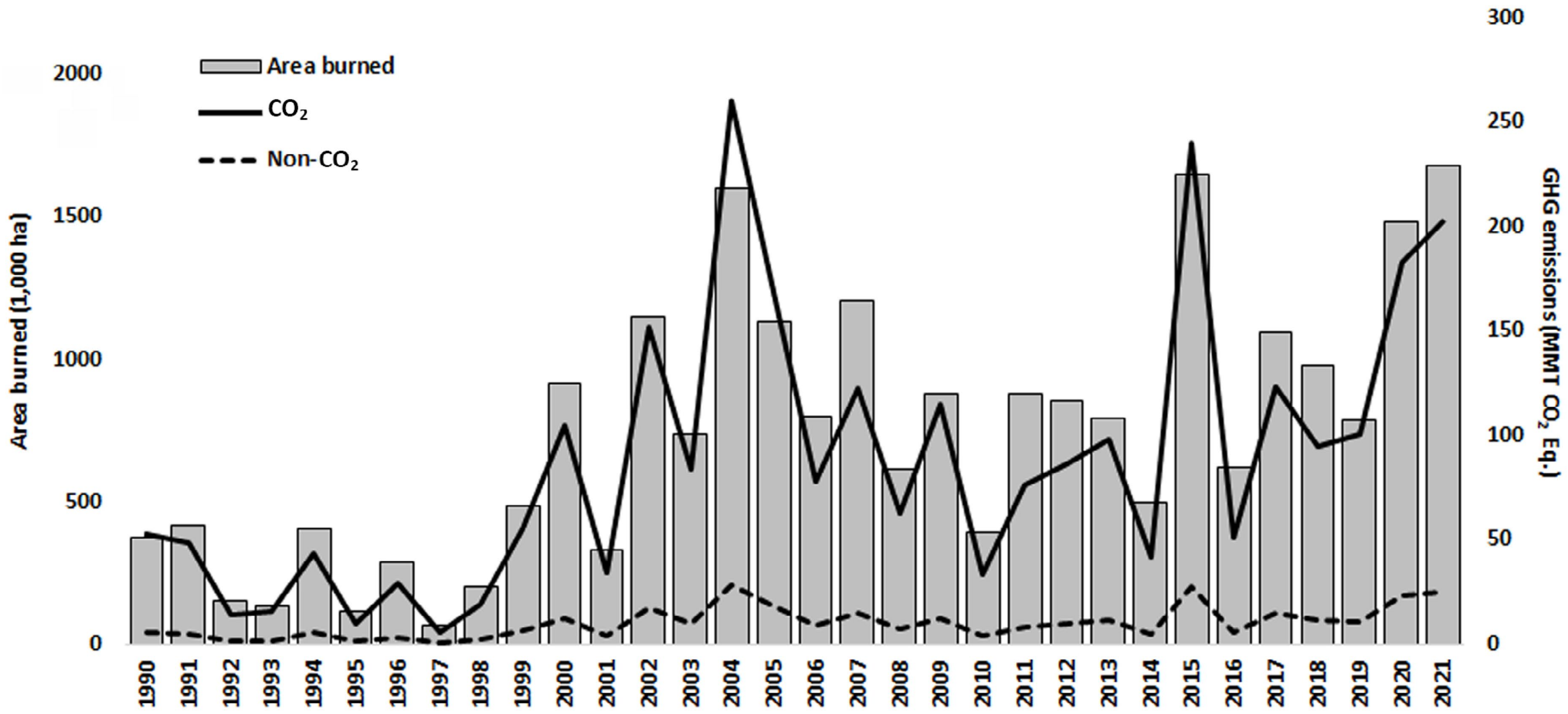
Quirion, Brendan R.; Domke, Grant M.; Walters, Brian F.; Lovett, Gary M.; Fargione, Joseph E.; Greenwood, Leigh; Serbesoff-King, Kristina; Randall, John M.; Fei, Songlin. 2021. Insect and Disease Disturbances Correlate With Reduced Carbon Sequestration in Forests of the Contiguous United States. Frontiers in Forests and Global Change. 4: 716582. 10 p. https://doi.org/10.3389/ffgc.2021.716582.

Stanke, Hunter; Finley, Andrew O.; Domke, Grant M.; Weed, Aaron S.; MacFarlane, David W. 2021. Over half of western United States' most abundant tree species in decline. Nature Communications. 12(1): 395-. https://doi.org/10.1038/s41467-020-20678-z.

Fitts, Lucia A.; Russell, Matthew B.; Domke, Grant M.; Knight, Joseph K. 2021. Modeling land use change and forest carbon stock changes in temperate forests in the United States. Carbon Balance and Management. 16(1): 4. 16 p. https://doi.org/10.1186/s13021-021-00183-6.

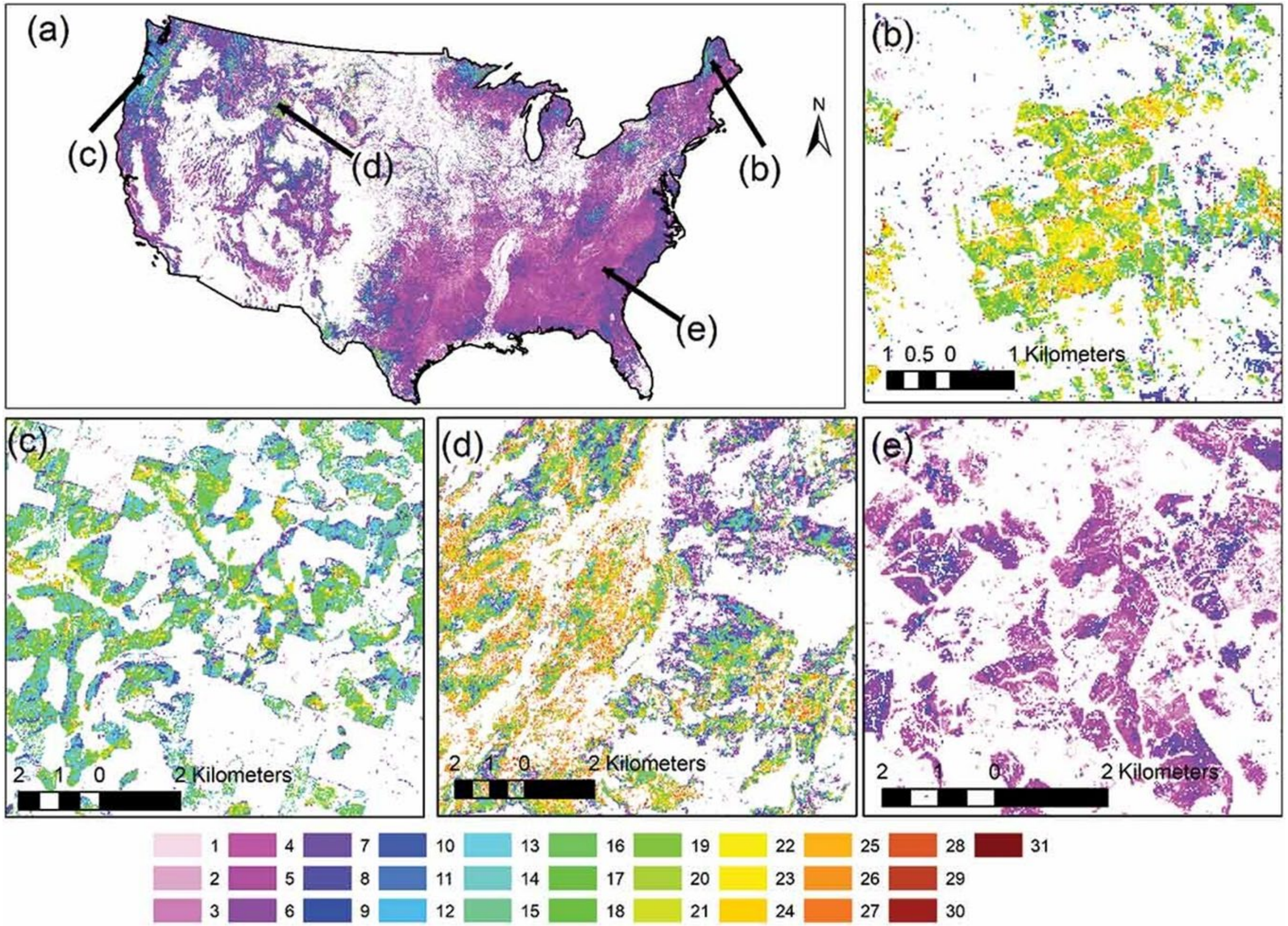
Xu, Liang; Saatchi, Sassan S.; Yang, Yan; Yu, Yifan; Pongratz, Julia; Bloom, A. Anthony; Bowman, Kevin; Worden, John; Liu, Junjie; Yin, Yi; Domke, Grant; McRoberts, Ronald E.; Woodall, Christopher; Nabuurs, Gert-Jan; de-Miguel, Sergio; Keller, Michael; Harris, Nancy; Maxwell, Sean; Schimel, David. 2021. Changes in global terrestrial live biomass over the 21st century. Science Advances. 7(27): eabe9829. 18 p. https://doi.org/10.1126/sciadv.abe9829.

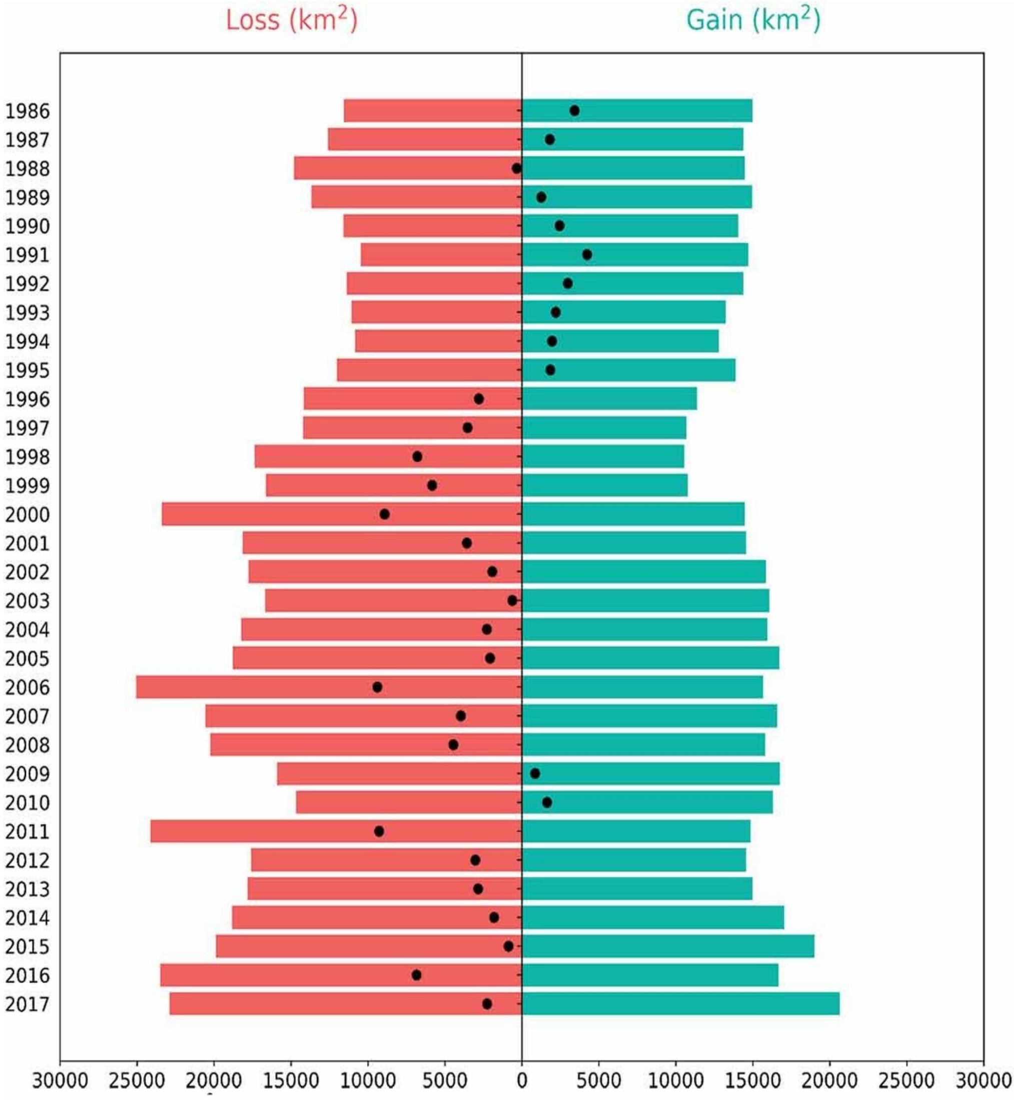
Area burned and fire emissions



Domke, G.M. et al. 2023. Greenhouse gas emissions and removals from forest land, woodlands, urban trees, and harvested wood products in the United States, 1990–2021. Resource Bulletin WO-101. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Washington Office. 10 p. https://doi.org/10.2737/WO-RB-101.

Reforestation and recovery of tree cover

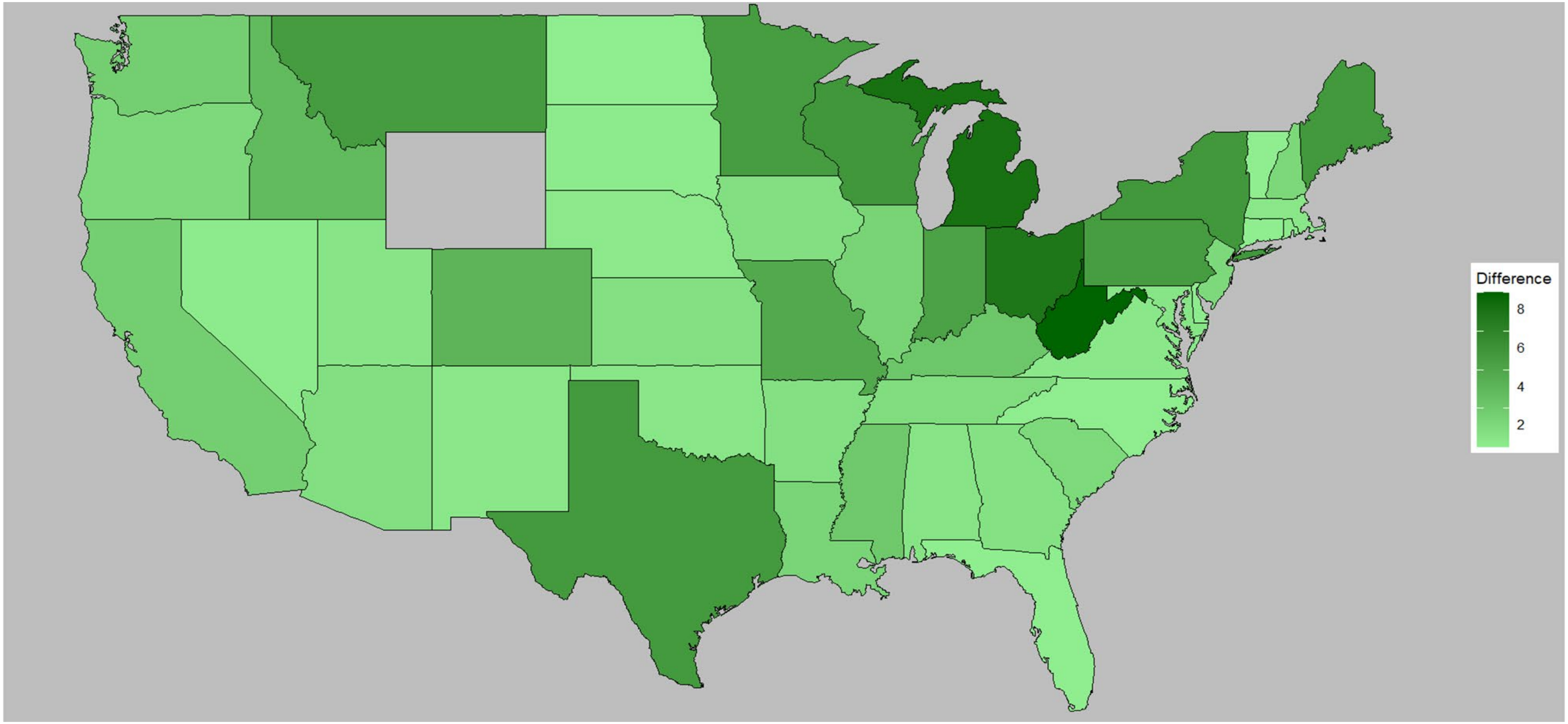




Zhou, Q., Xian, G., Horton, J., Wellington, D., Domke, G., Auch, R., Li, C. and Zhu, Z., 2022. Tree regrowth duration map from LCMAP collection 1.0 land cover products in the conterminous United States, 1985–2017. GIScience & Remote Sensing, 59(1), pp.959-974. https://doi.org/10.1080/15481603.2022.2083790

Advances in estimation and reporting, 2023-2024

- National Scale Volume and Biomass (NSVB) models



Westfall, J.A., Coulston, J.W., Gray, A.N., Shaw, J.D., Radtke, P.J., Walker, D.M., Weiskittel, A.R., MacFarlane, D.W., Affleck, D.L.R., Zhao, D., Temesgen, H., Poudel, K.P., Frank, J.M., Prisley, S.P., Wang, Y., Sánchez Meador, A.J., Auty, D., and Domke, G.M. 2023. A national-scale tree volume, biomass, and carbon modeling system for the United States. Gen. Tech. Rep. WO-XXX

Advances in estimation and reporting, 2023-2024

- National Scale Volume and Biomass (NSVB) models
  - Live and standing dead trees
  - Litter
- Extending CONUS methods to coastal Alaska
- Including HI, Pacific Affiliated Islands, and Caribbean Islands
- Litter and soil model predictions now in FIADB
- Improved consistency in land representation
  - Cropland and grassland conversions
  - Wetlands and other lands
- Improved fire emissions estimation
  - WFEIS-based estimates now include MTBS-, WFIGS-, and MODIS-based burns
  - MTBS- and WFIGS-based estimates are now calculated per burn event (i.e., separately for each forest fire)

Final thoughts

- Nature-based solutions need to be considered as part of a portfolio approach for climate change mitigation
- Trees, forests, and harvested wood products represent some of the greatest opportunities
  - Enhance carbon sequestration capacity
  - Avoided emissions
  - Substitution of fossil fuels
  - More than just carbon
- We must be realistic and work with nature and consider all lands and people

Thank you

Grant Domke: grant.m.domke@usda.gov

FIA program: www.fia.fs.usda.gov/

FIA carbon: www.fia.fs.usda.gov/forestcarbon/

NSVB models: www.fs.usda.gov/research/research/inventory/FIA/VBC

NCA5: www.globalchange.gov/nca5