

Supplementary Information

Article: Mapping forest-based natural climate solutions

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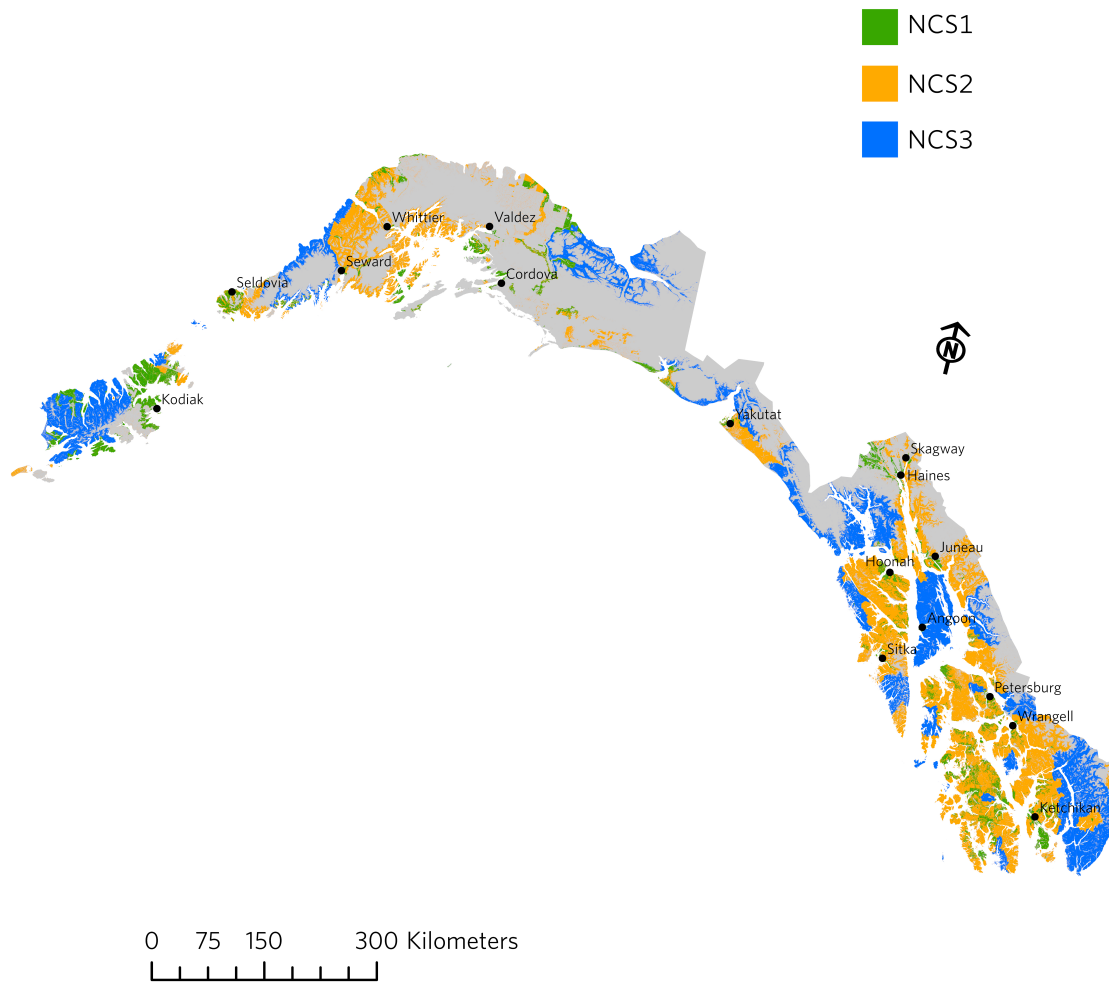
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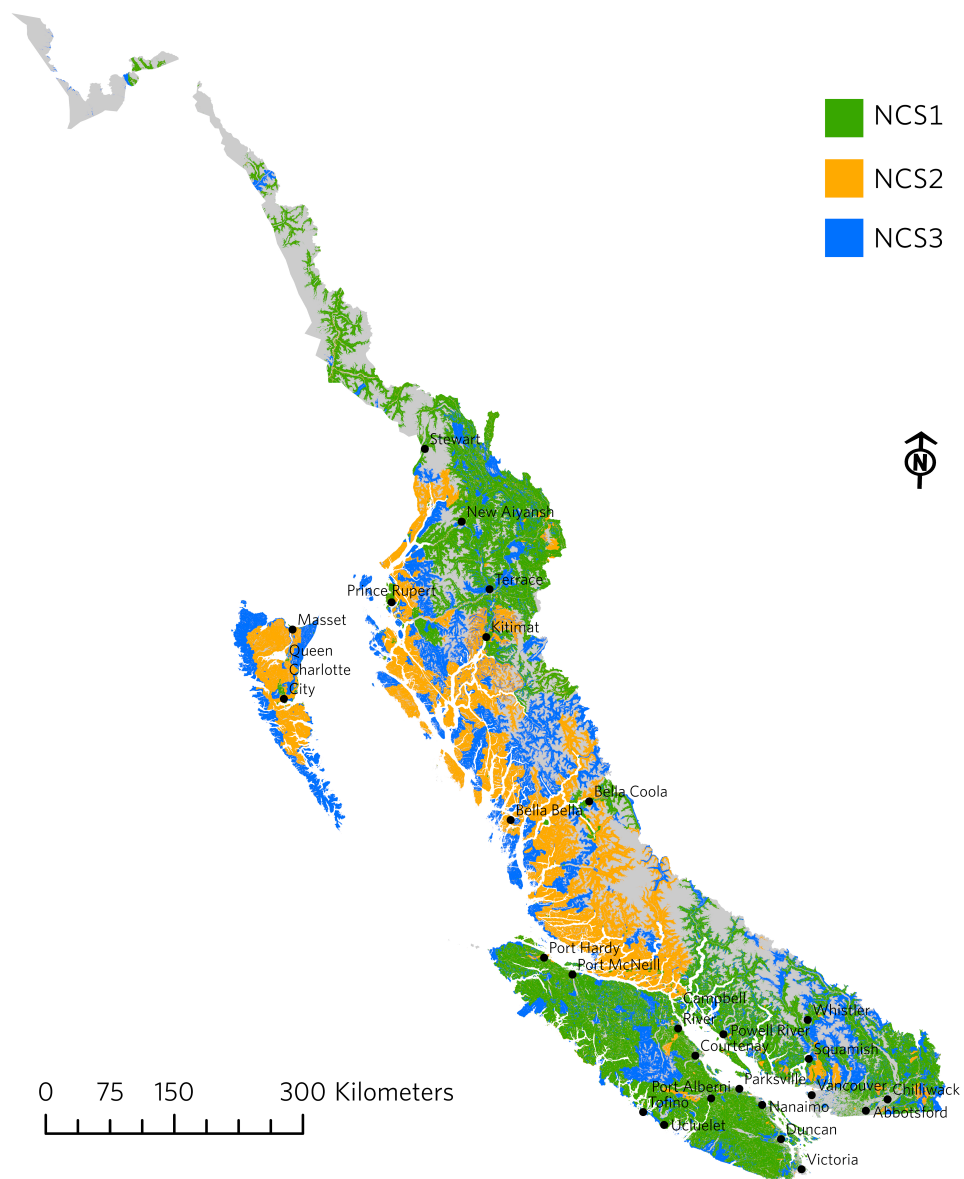
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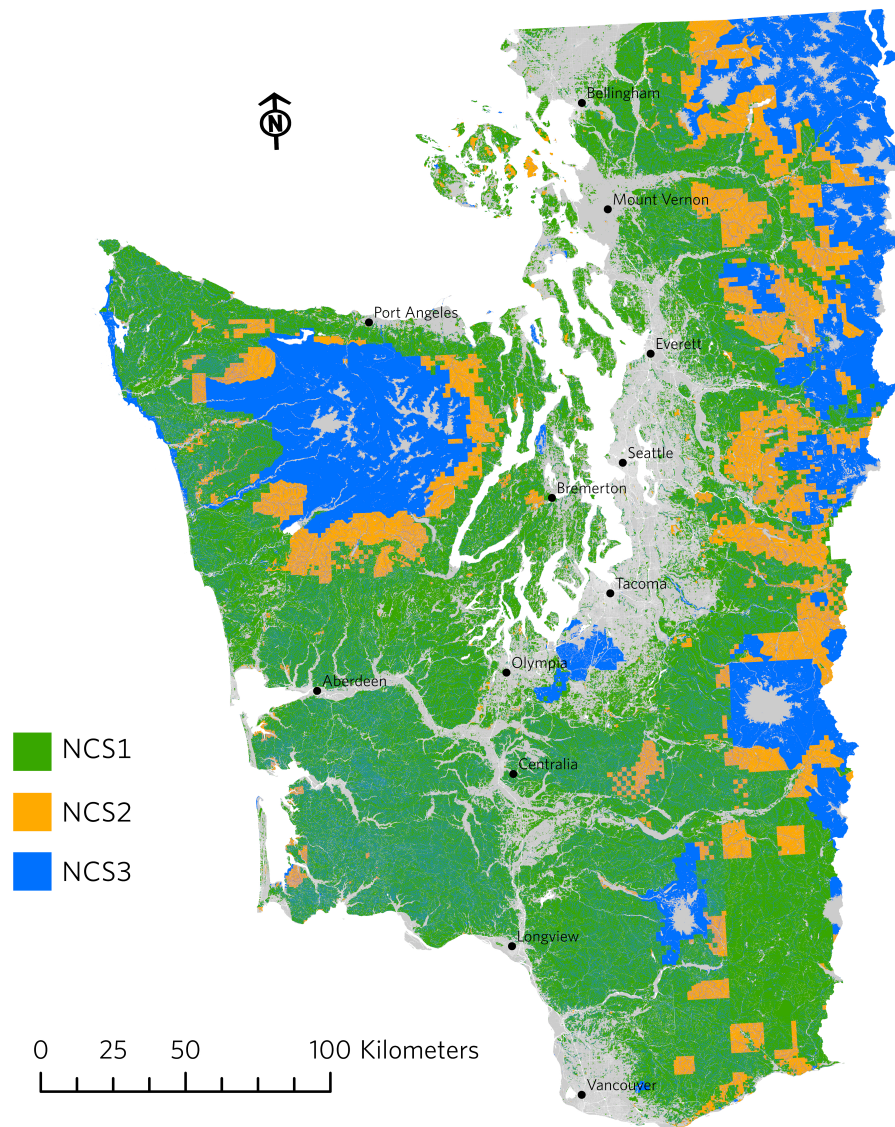
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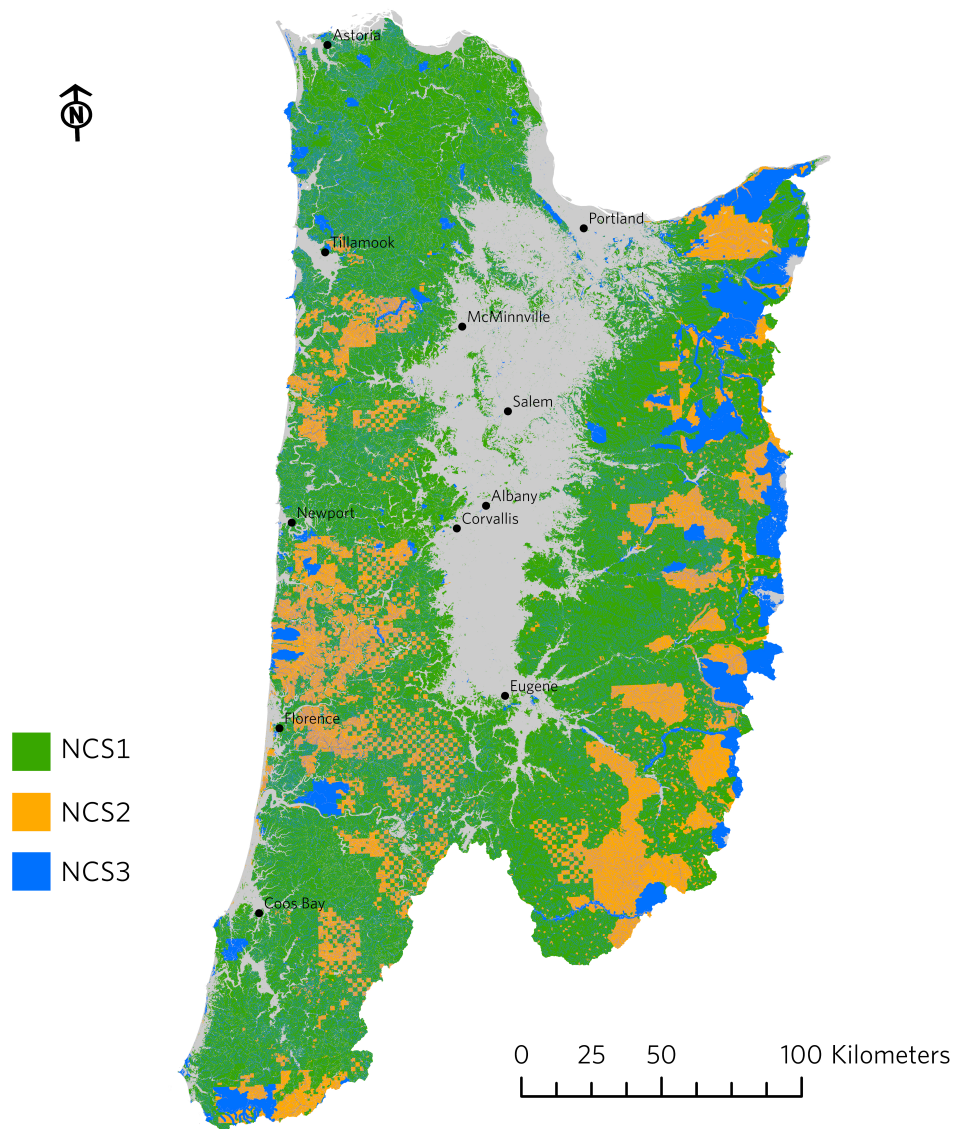
Supplemental Fig. 1 Natural Climate Solution (NCS) Action Category map for coastal temperate rainforests of Alaska, USA. NCS1 is available for action. NCS2 is not currently available for action. NCS3 is protected. Grey areas are non-forested or have unknown forest management plans.



Supplemental Fig. 2 Natural Climate Solution (NCS) Action Category map for coastal temperate rainforests of British Columbia, Canada. NCS1 is available for action. NCS2 is not currently available for action. NCS3 is protected. Grey areas are non-forested.



Supplemental Fig. 3 Natural Climate Solution (NCS) Action Category map for coastal temperate rainforests of Washington, USA. NCS1 is available for action. NCS2 is not currently available for action. NCS3 is protected. Grey areas are non-forested.



Supplemental Fig. 4 Natural Climate Solution (NCS) Action Category map for coastal temperate rainforests of Oregon, USA. NCS1 is available for action. NCS2 is not currently available for action. NCS3 is protected. Grey areas are non-forested.

Supplemental Table 1 Total area (ha) of tree cover loss (2001-2021) ¹, tree loss from fire (ha)², and percent of total loss from fire for the coastal temperate rainforest ecoregion of western North America.

Climate domain	Tree cover loss (ha)	Tree cover loss from fire (ha)	% fire loss of total loss (2001-2021)
All Tropics	215,285,645	18,424,853	9
Temperate	51,830,896	8,657,005	17
Subtropical	49,960,175	9,974,609	20
Boreal	118,170,882	81,914,587	69
Coastal temperate rainforests of western North America	2,542,812	323,007	13

Supplemental Table 2 Classification of Nature Climate Solutions (NCS) Action Category based on jurisdiction and land use designation for the coastal temperate rainforest ecoregion of western North America.

Jurisdiction	NCS Action Category	Designation
AK	0	Unknown Forest Management Plan
AK	1	Alaska Native Corporation
AK	1	Haines Alaska State Forest
AK	1	Indigenous Reservation
AK	1	Local government
AK	1	Alaska Mental Health Trust Investment Lands
AK	1	Private
AK	1	Southeast Alaska State Forest
AK	1	Tongass Suitable (with Roadless Rule)
AK	1	University of Alaska Investment Trust Lands
AK	2	Active Forest Carbon Project
AK	2	BLM – Bureau of Land Management
AK	2	Coastal Buffer
AK	2	GAP 2 – Gap Analysis Program Status 2
AK	2	State Park
AK	2	Stream Buffer
AK	2	Tongass Non-Suitable Timber
AK	2	Tongass Suitable (no Roadless Rule)
AK	2	Water Feature Buffer
AK	2	Waterbody Buffer
AK	3	GAP 1 - Gap Analysis Program Status 1
BC	1	Christmas Tree License
BC	1	Community Forest Agreement
BC	1	First Nation Woodland License

BC	1	Forest Management Unit
BC	1	Heritage Site
BC	1	Indian Reserve
BC	1	Land Claim Settlement
BC	1	Miscellaneous Lease
BC	1	Municipal Parcels
BC	1	Private
BC	1	Timber License
BC	1	Tree Farm License
BC	1	Unknown
BC	1	Woodlot
BC	2	Community Forest Agreement: Riparian buffers
BC	2	Community Watershed
BC	2	Crown UREP
BC	2	Federal Non-industrial
BC	2	Federal Reserve
BC	2	FN Woodland License: Riparian buffers
BC	2	Forest Management Unit: Great Bear Rainforest
BC	2	Forest Management Unit: Riparian buffers
BC	2	Forest Recreation Reserves
BC	2	Indian Reserve: Riparian buffers
BC	2	Land Claim Settlement: Riparian buffers
BC	2	Military Reserve
BC	2	Miscellaneous Lease: Riparian buffers
BC	2	Miscellaneous Reserve: Riparian buffers
BC	2	Municipal Parcels: Riparian buffers
BC	2	Private: Riparian buffers
BC	2	Recreation Area
BC	2	Special Forest Management Area
BC	2	Timber Alienated in Watershed
BC	2	Timber License: Great Bear Rainforest
BC	2	Timber License: Riparian buffers
BC	2	Tree Farm License: Great Bear Rainforest
BC	2	Tree Farm License: Riparian buffers
BC	2	Unknown: Riparian buffers
BC	2	Watershed Reserve
BC	2	Woodlot: Riparian buffers
BC	3	Crown Biodiversity Mining Tourism Area
BC	3	Ecological Reserve
BC	3	Environmental Non-Government Organization or Private Protected
BC	3	Environmental Non-Government Organization Protected

BC	3	Local Park
BC	3	Migratory Bird Sanctuary
BC	3	Miscellaneous Reserve
BC	3	National Park
BC	3	National Wildlife Area
BC	3	Nature Reserve
BC	3	Old Growth Management Area
BC	3	Provincial Park
BC	3	Regional Park
BC	3	Wildland Zones
BC	3	Wildlife Habitat Areas
BC	3	Wildlife Management Area
OR	1	BLM - Multiple-use public land
OR	1	Indigenous
OR	1	NWFP - Adaptive Management Areas
OR	1	NWFP - Matrix, Riparian Reserve and other unmapped
OR	1	ODF - Multiple-use public land
OR	1	ODSL - Multiple-use public land
OR	1	OUS - Multiple-use public land
OR	1	Private - Assumed non-industrial
OR	1	Private - Family
OR	1	Private - Integrated
OR	1	Private - Medium
OR	1	Private - PI
OR	1	Private - REIT
OR	1	Private - Small
OR	1	Private - TIMO
OR	1	Private - Very Small
OR	1	USFS - Multiple-use public land
OR	2	BLM - Wilderness Study Area
OR	2	FWS - Research Natural Area
OR	2	FWS - Wilderness Study Area
OR	2	Local Government
OR	2	NWFP - Adaptive Management Areas, reserved
OR	2	NWFP - Administratively Withdrawn
OR	2	NWFP - Late-Successional Reserves
OR	2	NWFP - Marbled Murrelet Reserves
OR	2	NWFP - Northern Spotted Owl Activity Cores
OR	2	USFS - Experimental Forest
OR	2	USFS - National Scenic Area
OR	2	USFS - Research Natural Area
OR	2	USFS - Wild and Scenic River Study Area
OR	2	USFS - Wilderness Study Area

OR	3	BIA - Fish-bearing stream riparian buffers
OR	3	BIA - Non fish-bearing riparian buffers
OR	3	BLM - Conservation Area
OR	3	BLM - Fish-bearing stream riparian buffers
OR	3	BLM - Non fish-bearing riparian buffers
OR	3	BLM - Non fish-bearing stream buffer
OR	3	BLM - Wild and Scenic River
OR	3	BLM - Wilderness Area
OR	3	BPA - Facility
OR	3	BPA - Fish-bearing stream riparian buffers
OR	3	BPA - Non fish-bearing riparian buffers
OR	3	DOD - Facility
OR	3	DOD - Non fish-bearing riparian buffers
OR	3	DOE - Facility
OR	3	DOE - Fish-bearing stream riparian buffers
OR	3	DOL - Facility
OR	3	DOL - Non fish-bearing riparian buffers
OR	3	FWS - Fish-bearing stream riparian buffers
OR	3	FWS - National Wildlife Refuge
OR	3	FWS - Non fish-bearing riparian buffers
OR	3	FWS - Wilderness Area
OR	3	GSA - Facility
OR	3	GSA - Fish-bearing stream riparian buffers
OR	3	GSA - Non fish-bearing riparian buffers
OR	3	LG - Fish-bearing stream riparian buffers
OR	3	LG - Laverne County Park
OR	3	LG - Middle Creek County Park
OR	3	LG - Non fish-bearing riparian buffers
OR	3	LG - Rock Prairie County Park
OR	3	Local Government
OR	3	NGO
OR	3	NGO - Fish-bearing stream riparian buffers
OR	3	NGO - Non fish-bearing riparian buffers
OR	3	NGO - Private Conservation
OR	3	NPS - Fish-bearing stream riparian buffers
OR	3	NPS - National Park
OR	3	NPS - Non fish-bearing riparian buffers
OR	3	ODF - Facility
OR	3	ODF - Fish-bearing stream riparian buffers
OR	3	ODF - Non fish-bearing riparian buffers
OR	3	ODFW - Fish-bearing stream riparian buffers
OR	3	ODFW - Non fish-bearing riparian buffers
OR	3	ODFW - State Natural Area

OR	3	ODOT
OR	3	ODOT - Fish-bearing stream riparian buffers
OR	3	ODOT - Non fish-bearing riparian buffers
OR	3	ODSL - Fish-bearing stream riparian buffers
OR	3	ODSL - Non fish-bearing riparian buffers
OR	3	OPRD - Fish-bearing stream riparian buffers
OR	3	OPRD - Non fish-bearing riparian buffers
OR	3	OPRD - State Natural Area
OR	3	OR - Unknown
OR	3	OUS - Facility
OR	3	OUS - Fish-bearing stream riparian buffers
OR	3	OUS - Non fish-bearing riparian buffers
OR	3	Private - Fish-bearing stream riparian buffers
OR	3	Private - Non fish-bearing riparian buffers
OR	3	Private Family - Fish-bearing stream riparian buffers
OR	3	Private Family - Non fish-bearing riparian buffers
OR	3	Private Integrated - Fish-bearing stream riparian buffers
OR	3	Private Integrated - Non fish-bearing riparian buffers
OR	3	Private Medium - Fish-bearing stream riparian buffers
OR	3	Private Medium - Non fish-bearing riparian buffers
OR	3	Private PI - Fish-bearing stream riparian buffers
OR	3	Private PI - Non fish-bearing riparian buffers
OR	3	Private REIT - Fish-bearing stream riparian buffers
OR	3	Private REIT - Non fish-bearing riparian buffers
OR	3	Private Small - Fish-bearing stream riparian buffers
OR	3	Private Small - Non fish-bearing riparian buffers
OR	3	Private TIMO - Fish-bearing stream riparian buffers
OR	3	Private TIMO - Non fish-bearing riparian buffers
OR	3	Private Very Small - Fish-bearing stream riparian buffers
OR	3	Private Very Small - Non fish-bearing riparian buffers
OR	3	State - Fish-bearing stream riparian buffers
OR	3	State - Non fish-bearing riparian buffers
OR	3	USACE - Facility
OR	3	USACE - Fern Ridge Lake
OR	3	USACE - Fish-bearing stream riparian buffers
OR	3	USACE - Non fish-bearing riparian buffers
OR	3	USCG - Facility
OR	3	USCG - Fish-bearing stream riparian buffers
OR	3	USFS - Conservation Area
OR	3	USFS - Fish-bearing stream riparian buffers
OR	3	USFS - Multiple-use public land
OR	3	USFS - Non fish-bearing riparian buffers
OR	3	USFS - Wild and Scenic River

OR	3	USFS - Wilderness Area
OR	3	VA - Non fish-bearing riparian buffers
OR	3	VA - Facility
OR	3	Water
OR	3	Water - Fish-bearing stream riparian buffers
OR	3	Water - Non fish-bearing riparian buffers
WA	1	ACC - Access Area
WA	1	AGRE - Agricultural Easement
WA	1	FORE - Forest Stewardship Easement
WA	1	FOTH - Federal Other or Unknown Designation
WA	1	LOTH - Local Other or Unknown
WA	1	LP - Local Park
WA	1	LREC - Local Recreation Area
WA	1	LRMA - Local Resource Management Area
WA	1	ND - Not Designated
WA	1	NF - National Forest
WA	1	NRA - National Recreation Area
WA	1	OTHE - Other Easement
WA	1	POTH - Private Other or Unknown
WA	1	Private - Industrial Forest Land
WA	1	Private - Small Forest Land Owners
WA	1	Private - Unknown Management
WA	1	PUB - National Public Lands
WA	1	REC - Recreation Management Area
WA	1	RECE - Recreation or Education Easement
WA	1	SOTH - State Other or Unknown
WA	1	SP - State Park
WA	1	SREC - State Recreation Area
WA	1	SRMA - State Resource Management Area
WA	1	TRIBL - Native American Land Area
WA	1	WPA - Watershed Protection Area
WA	1	WSR - Wild and Scenic River
WA	2	ACEC - Area of Critical Environmental Concern
WA	2	CONE - Conservation Easement
WA	2	HCA - Historic or Cultural Area
WA	2	HCAE - Historic or Cultural Easement
WA	2	IRA - Inventoried Roadless Area
WA	2	LCA - Local Conservation Area
WA	2	LHCA - Local Historic or Cultural Area
WA	2	NCA - Conservation Area
WA	2	NM - National Monument
WA	2	NSBV - National Scenic, Botanical or Volcanic Area
WA	2	NT - National Scenic or Historic Trail

WA	2	PCON - Private Conservation
WA	2	PFOR - Private Forest Stewardship
WA	2	PREC - Private Recreation or Education
WA	2	SCA - State Conservation Area
WA	2	UNKE - Unknown Easement
WA	2	WA - Wilderness Area
WA	3	ACC - Access Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	ACEC - Area of Critical Environmental Concern - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	AGRE - Agricultural Easement - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	CONE - Conservation Easement - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	FORE - Forest Stewardship Easement - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	FOTH - Federal Other or Unknown Designation - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	HCA - Historic or Cultural Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	IRA - Inventoried Roadless Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	LCA - Local Conservation Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	LHCA - Local Historic or Cultural Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	LOTH - Local Other or Unknown - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	LP - Local Park - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	LREC - Local Recreation Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	LRMA - Local Resource Management Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	MIL - Military Land
WA	3	MIL - Military Land - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	NCA - Conservation Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	ND - Not Designated - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	NF - National Forest - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	NM - National Monument - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	NP - National Park

WA	3	NP - National Park - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	NRA - National Recreation Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	NSBV - National Scenic, Botanical or Volcanic Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	NT - National Scenic or Historic Trail - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	NWR - National Wildlife Refuge
WA	3	NWR - National Wildlife Refuge - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	OTHE - Other Easement - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	PCON - Private Conservation - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	PFOR - Private Forest Stewardship - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	POTH - Private Other or Unknown - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	PREC - Private Recreation or Education - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	Private - Industrial Forest Land - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	Private - Small Forest Land Owners - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	Private - Unknown Management - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	PUB - National Public Lands - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	REC - Recreation Management Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	RECE - Recreation or Education Easement - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	SCA - State Conservation Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	SOTH - State Other or Unknown - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	SP - State Park - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	SREC - State Recreation Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	SRMA - State Resource Management Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	TRIBL - Native American Land Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	UNKE - Unknown Easement - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	WA - Wilderness Area - Riparian & wetland buffers simulating WA Forest Practice Rules

WA	3	Water
WA	3	Water - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	WPA - Watershed Protection Area - Riparian & wetland buffers simulating WA Forest Practice Rules
WA	3	WSR - Wild and Scenic River - Riparian & wetland buffers simulating WA Forest Practice Rules

Supplemental Table 3 Area (ha) and percentage of jurisdictional totals by Natural Climate Solutions (NCS) Action Category for the coastal temperate rainforest ecoregion of western North America. The area calculations are masked to forested areas only (see Methods). The results are converted to two significant digits and may not sum exactly.

NCS Action Category	AK (ha)	BC (ha)	WA (ha)	OR (ha)	Ecoregion Total (ha)
1	1,100,00 (12%)	6,700,000 (46%)	2,800,000 (57%)	2,600,000 (63%)	13,000,000 (40%)
2	4,500,000 (50%)	4,200,000 (28%)	640,000 (13%)	680,000 (17%)	10,000,000 (30%)
3	3,400,000 (38%)	3,900,000 (26%)	1,500,000 (30%)	820,000 (20%)	9,700,000 (29%)

Supplemental Table 4 The timber volume harvested for the year 1996, 2006, and 2016 for Alaska, USA, the Pacific Northwest (Washington and Oregon), USA³, and British Columbia, Canada⁴ with the coefficient of variation (CV).

Region	Volume harvested by year (cubic meters)			CV
	1996	2006	2016	
Alaska, USA	5,168,581	1,872,986	1,105,233	79%
British Columbia, Canada	72,252,291	80,059,018	66,379,661	9%
Pacific Northwest, USA	48,732,420	54,903,352	53,573,369	6%
Totals	126,153,291	136,835,356	121,058,263	10%

Supplemental Table 5 The percent area of dominant drivers of tree cover loss (2001-2021)⁵ for NCS Action Category 1 (NCS1) for the coastal temperate rainforest ecoregion of western North America.

Tree cover loss by dominant driver 2001-2021

Region	Commodity driven deforestation	Forestry	Shifting agriculture	Urbanization	Wildfire	None
Alaska, USA	0%	32%	0%	0%	4%	63%
British Columbia, Canada	0%	76%	0%	2%	2%	19%
Washington, USA	0%	82%	0%	14%	0%	3%
Oregon, USA	0%	96%	0%	3%	0%	1%
Regional Summary	0%	78%	0%	5%	1%	15%

Supplemental Table 6 The forest carbon balance by private land ownership types that are available for NCS action (NCS Action Category 1) in the coastal temperate rainforests of Washington, USA. The totals differ slightly from Table 2 in the manuscript because some private lands have designations that do not clearly place them in one of the three categories analyzed here. The results were converted to two significant digits and may not sum exactly.

Private Ownership Types	Avg. Ann. Sequestration (MtCO ₂ yr ⁻¹)	Avg. Ann. Carbon Losses (MtCO ₂ e yr ⁻¹)	Avg. Ann. Net Balance (MtCO ₂ e yr ⁻¹)
Private - Industrial Forest Land	13	-17	-3.8
Private - Small Forest Land Owners	6.7	-2.8	3.9
Private - Unknown Management	3.0	-1.2	1.8
Totals	23	-21	1.8

Supplemental Table 7 A comparison of average annual forest carbon flux summarized from the most recent USFS Forest Inventory and Analysis Program (FIA) remeasurement reports for Alaska, USA (2004-2013)⁶, Washington, USA (2002-2016)⁷, and Oregon, USA (2001-2016)⁸, with Harris et al. 2021⁹ (2001-2021) for the entire study area (not exclusive to NCS1 lands in Table 2). For Alaska, Indigenous and Private lands were combined to match the FIA categories. The USFS FIA data summarizes changes in forest biomass between inventory periods. Gross sequestration represents forest growth and increases in biomass in all five carbon pools between the inventory periods. Gross emissions include mortality and removals from FIA data. The FIA data do not include emissions due to forest conversion to other land uses or non-carbon greenhouse gas emissions due to fires. Thus, they are not immediately comparable to the Harris et al. 2021⁹ sequestration and emission data.

	FIA Method			Harris et al. 2021 Method		
	Gross Sequestration (MtCO ₂ e/yr)	Gross Emissions (MtCO ₂ e/yr)	Net Balance (MtCO ₂ e/yr)	Gross Sequestration (MtCO ₂ e/yr)	Gross Emissions (MtCO ₂ e/yr)	Net Balance (MtCO ₂ e/yr)
<i>Alaska</i>						
Federal	16.9	-13.4	3.5	55.0	-0.5	54.5
State and Local	4.6	-2.4	2.2	8.4	-0.2	8.2
Private	3.7	-5.3	-1.6	6.7	-0.7	6.0
Subtotal	25.2	-21.1	4.1	70.1	-1.5	68.7
<i>Washington</i>						
Federal	22.1	-11.5	10.6	20.4	-1.7	18.7
State	8.8	-8.8	0	7.5	-4.8	2.7
Local	3.1	-1.6	1.5	1.9	-0.4	1.5
Private	30.6	-27.7	2.9	29.1	-24.3	4.8
Indigenous	na	na	na	1.6	-0.6	1
Subtotal	64.6	-49.6	15	60.5	-31.8	28.7
<i>Oregon</i>						
Federal	34.8	-14.2	20.6	17.3	-11.2	6.1
State and Local	4.8	-3.9	0.9	3.9	-3.1	0.8
Private	28.9	-29.1	-0.2	23.4	-41.4	-18
Indigenous	na	na	na	0.1	-0.1	0
Subtotal	68.5	-47.2	21.3	44.7	-55.8	-11.1

Supplementary References

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