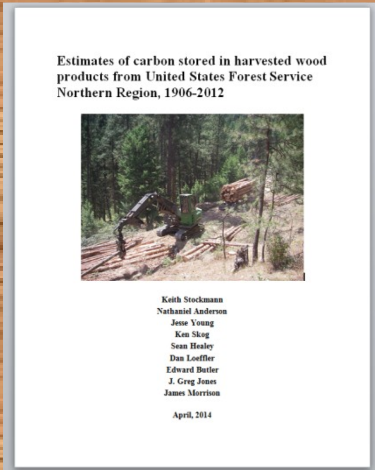
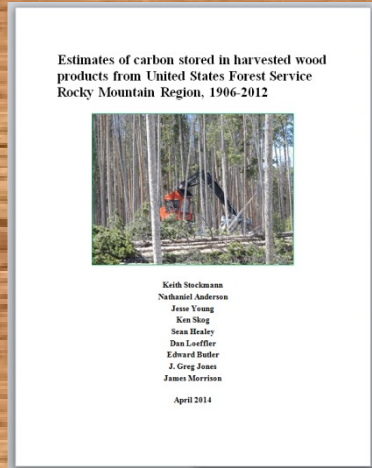


Estimates of carbon stored in harvested wood products from United States Forest Service Northern Region, 1906-2012

Keith Stockmann
Nathaniel Anderson
Jesse Young
Ken Skog
Sean Healey
Dan Loeffler
Edward Butler
J. Greg Jones
James Morrison

April, 2014



Estimates of carbon stored in harvested wood products from United States Forest Service Rocky Mountain Region, 1906-2012

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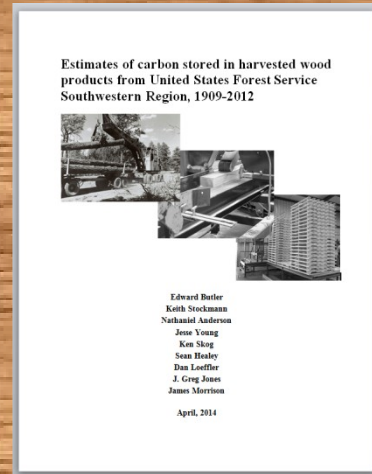

Estimates of carbon stored in harvested wood products from United States Forest Service Southwestern Region, 1909-2012

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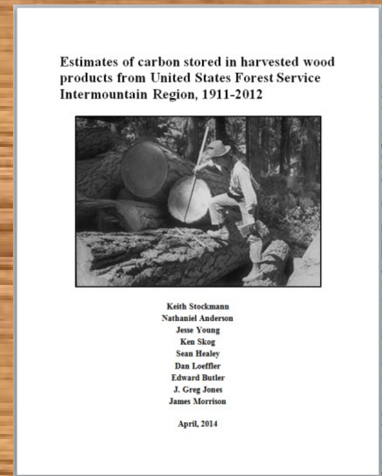

Estimates of carbon stored in harvested wood products from United States Forest Service Intermountain Region, 1911-2012

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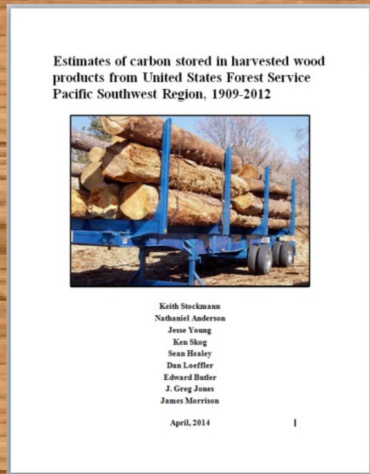

Estimates of carbon stored in harvested wood products from United States Forest Service Pacific Southwest Region, 1909-2012

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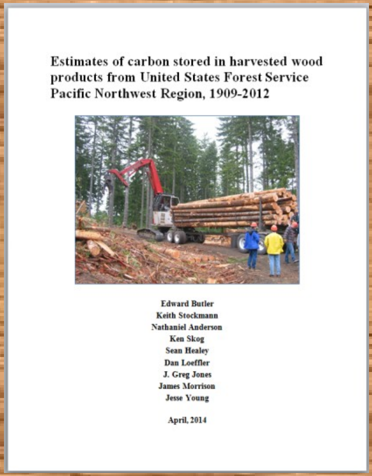
Harvested Wood Product Carbon Storage Estimates for All Regions of the National Forest System from Inception to 2012



Estimates of carbon stored in harvested wood products from United States Forest Service Pacific Northwest Region, 1909-2012

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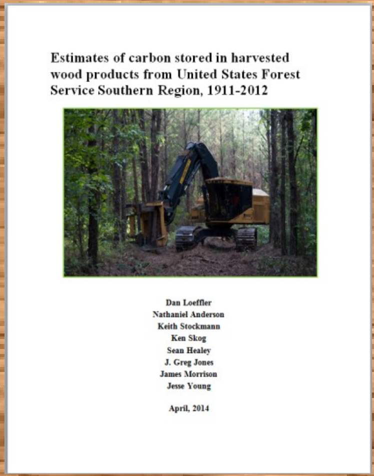

Estimates of carbon stored in harvested wood products from United States Forest Service Southern Region, 1911-2012

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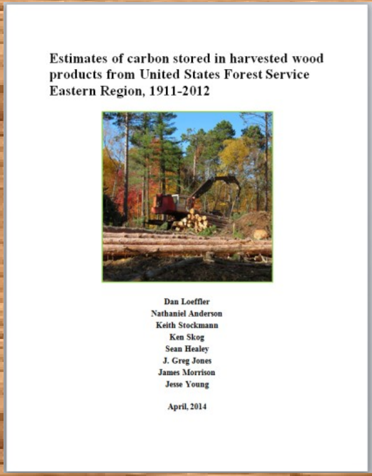

Estimates of carbon stored in harvested wood products from United States Forest Service Eastern Region, 1911-2012

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Jesse Young

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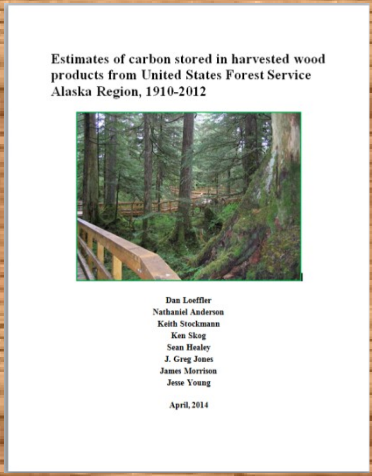


Estimates of carbon stored in harvested wood products from United States Forest Service Alaska Region, 1910-2012

Dan Loeffler
Nathaniel Anderson
Keith Stockmann
Ken Skog
Sean Healey
J. Greg Jones
James Morrison
Jesse Young

April, 2014

Keith Stockmann, PhD Western Forest Economists Meeting May 19th, 2014

Presentation Outline

- Overview fo the Forest Carbon Pool
- Harvested Wood Products Approach
- Data Used
- Aggregated National Harvest
- Summary of Regional Results
- Aggregated National Storage
- Aggregated National Emissions
- Aggregated National Net Annual Change
- Next Steps including an integrated look with Ecosystem Carbon

Why do this Modeling?

- The forest sector of the United States (US) currently stores about 45 billion megagrams of carbon (MgC), or the equivalent of about 24 years of total US emissions at the 2010 rate (US EPA 2012).
- Nationally, net additions to ecosystem and harvested wood products (HWP) pools have been estimated at 251.4 million MgC yr^{-1} (US EPA 2012), with US forests offsetting about 13.5% of the country’s annual fossil fuel emissions.
- About 5.5% of total US forest sector carbon stocks and 7.1% of the annual flux is attributable to carbon in HWP.
- Results suggest in 2006, 297,845,557 MgC of USDA Forest Service HWP C storage was **12.5%** of the 2,383TgC of US national HWP C storage
- National Forest System Lands represent about 8.5% of US land, with 39 of the 59 million hectares in timber land, which is about 19% of forest nationwide classified by FIA as timber lands.

The Big Carbon Picture

Total Ecosystem Carbon Stock = Soil Carbon + Standing Biomass + Downed Wood + Roots + Harvested Wood Products Carbon

Total Ecosystem Carbon Flux = ∆ Standing Biomass + ∆ Downed Wood + ∆ Roots + ∆ ***<u>Harvested Wood Products Carbon</u>***.

Where change (∆) is derived from forest disturbance such as wildland fire, insect and disease impacts and silvicultural activities (including wood products harvesting) and the forest growth response to all activities.

Important Equivalency:

$1x10^6$ g = 1 Mg = 1 tonne = 1 metric ton = 0.000001 Tg

HWP C in Context of Forest Carbon

Accounting Approach

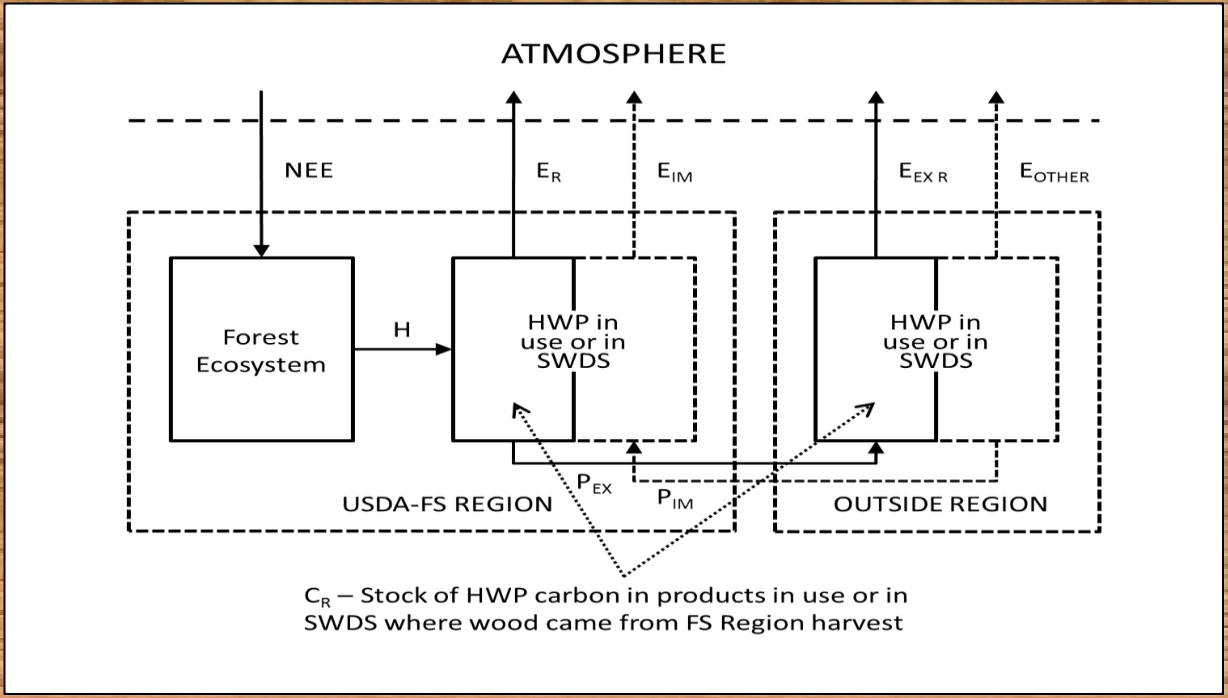
- We use the IPCC production accounting approach, which has been adopted by the US Environmental Protection Agency (EPA; hereafter referred to as the IPCC/EPA approach) to estimate annual changes in HWP pools from the Region
- In the IPCC/EPA approach, the annual carbon stock change for the Region’s forest sector is a function of carbon flow among the atmosphere, forest ecosystems, and HWP, and is calculated as:

$\Delta S = (NEE - H) + (\Delta C_R)$

Variable	Definition
ΔS	Annual carbon stock change, which is calculated as $\Delta S=(NEE-H)+(\Delta C_{R1})$ in the production accounting approach.
NEE	Annual net ecosystem carbon exchange, the annual net carbon that moves from the atmosphere to forests.
H	Annual harvest of wood for products, which includes wood and residues removed from harvest sites, but excludes resides left at harvest sites.
HWP	Harvested wood products in use or at solid waste disposal sites.
E_R	Annual emission of carbon to the atmosphere in the Region from products made from wood harvested in the Region.
E_{IM}	Annual emission of carbon to the atmosphere in the Region from products made from wood harvested outside of the Region and imported into the Region.
P_{EX}	Annual exports of wood and paper products out of the Region, including roundwood, chips, residue, pulp and recovered (recycled) products.
P_{IM}	Annual imports of wood and paper products into the Region, including roundwood, chips, residue, pulp and recovered (recycled) products.
$E_{EX\ R}$	Annual emission of carbon to the atmosphere in areas outside of the Region from products made from wood harvested in the Region.
E_{OTHER}	Annual emission of carbon to the atmosphere in areas outside of the Region from products made from wood harvested outside the Region.
C_R	Stock of harvested wood products carbon in use or at solid waste disposal sites where products used wood from the Region.
$\Delta C_{IU\ R}$	Annual change in carbon stored in harvested wood products in use where products used wood from the Region.
$\Delta C_{SWDS\ R}$	Annual change in carbon stored in harvested wood products at solid waste disposal sites where products used wood from the Region.
ΔC_R	Annual change in carbon stored in harvested wood products in use and at solid waste disposal sites where products used wood from the Region.

(Skog 2008). Units for all variables are MgC yr^{-1}

The Conceptual Framework



- Model at the regional level then aggregate for National totals
- The product life cycle is really a lag in emissions between the time a stand is cut and the time the carbon ends up back in the atmosphere. It ends up being an additional carbon storage pool as long as some level of harvesting continues.

The Data

- Harvest Data
  - 1906-1979 Archived NFS Harvest Data (total volumes in MBF, converted to CCF)
  - 1980-2012 NFS Cut – Sold Reports, electronic
- Wood to Carbon Estimates (GTR-343)
- Timber Product Data (Skog 1998)
- Primary Wood Product Data (GTR-343)
- End Use Data (Skog 1998)
- Disposition and Half-life data (Skog 2008)
- Timber Product Output information about processing facility timing (where available)

Conversions

- MBF to CCF varied slightly between regions
- Examples:

- Region 6 – PNW

Conversion	Units
1.9231	ccf per mbf, timber harvest prior to 2000
33 to 42	lbs per cubic foot, primary products
2204.6	lbs per Mg
0.95 to 1.0	Mg wood fiber per Mg product
0.5	Mg carbon per dry Mg wood fiber
0.711 to 0.919	MgC per ccf, primary products

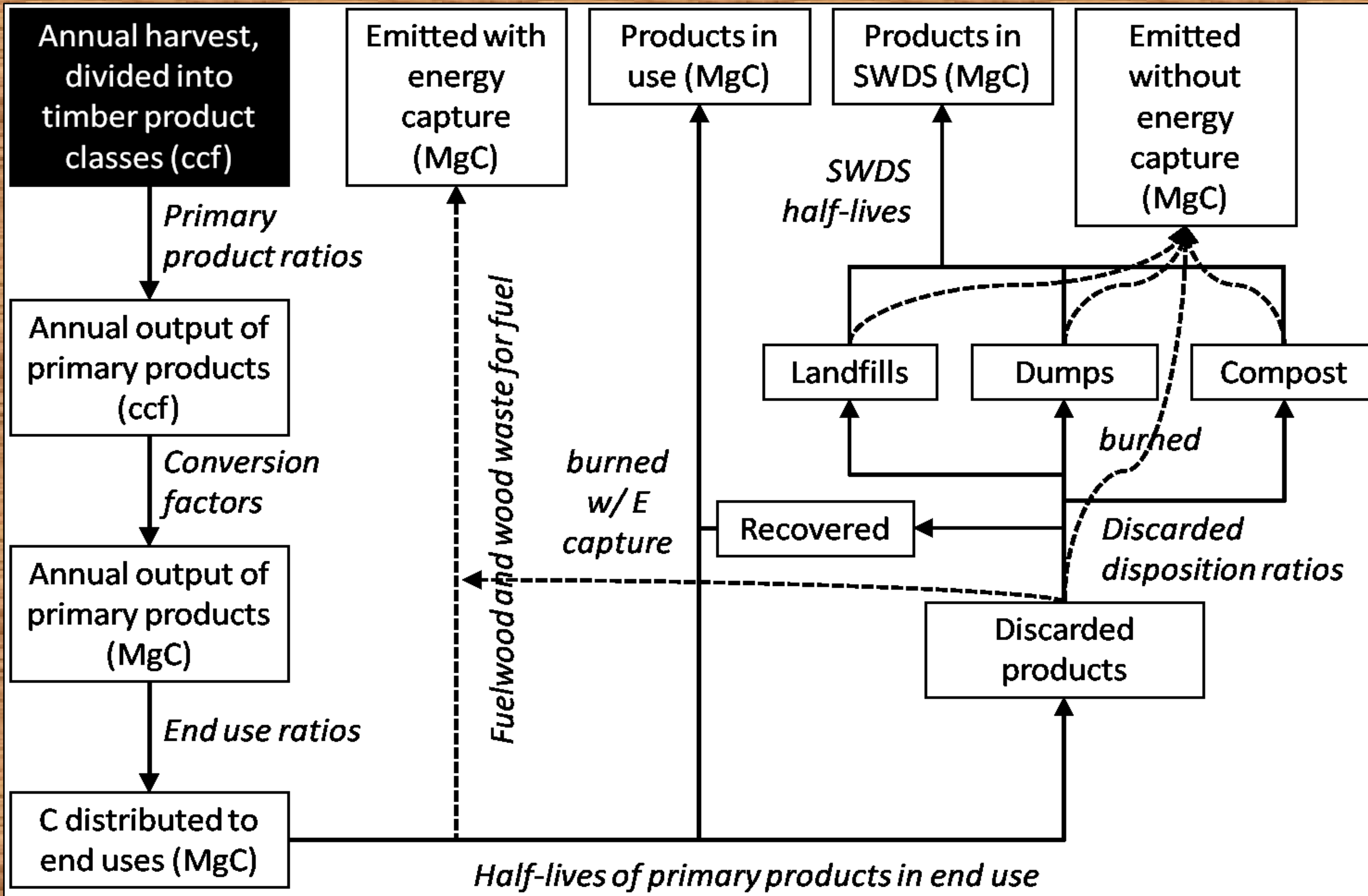
Region 8 - Southern

Conversion	Units
2.1443	ccf per mbf, timber harvest prior to 2000
33 to 42	lbs per cubic foot, primary products
2204.6	lbs per Mg
0.95 to 1.0	Mg wood fiber per Mg product
0.5	Mg carbon per dry Mg wood fiber
0.711 to 0.919	MgC per ccf, primary products

[1] Both mbf and ccf are available in all timber harvest reports after 2000.

Conversions

- There is new evidence that ccf per mbf conversion factors have changed in recent decades. For example, Keegan et al. (2010a) has found 23% and 19% increases in ccf per mbf conversions in Oregon and Washington, respectively, from 1970 to 2000s. This alone would suggest our conversions from mbf to ccf in earlier decades, overestimate the volume harvested. On the other hand, Keegan et al. (2010b) indicates that the utilization represented as cubic feet of green finished lumber per cubic foot of bole wood processed has increased during the same period, by roughly the same magnitude (Oregon 24%, Washington 16%). This would suggest our estimates of carbon volume moved into products in use was underestimated in earlier decades.
- **Given that these two essentially cancel each other out** and the fact that we did not have adequate data specific to wood cut from national forests across the entire period we chose not to incorporate this information into our calculations.
- **Analyses similar to those found in Keegan et al (2010a, 2010b) are not available for all USFS Regions**.


Annual harvest, divided into timber product classes (ccf)
Primary product ratios
Annual output of primary products (ccf)
Conversion factors
Annual output of primary products (MgC)
End use ratios
C distributed to end uses (MgC)
Emitted with energy capture (MgC)
Fuelwood and wood waste for fuel
burned w/ E capture
Products in use (MgC)
Products in SWDS (MgC)
SWDS half-lives
Emitted without energy capture (MgC)
Landfills
Dumps
Compost
burned
Recovered
Discarded disposition ratios
Discarded products
Half-lives of primary products in end use

Distribution Examples

- Products in Use, Fuel Wood and Waste Wood with Energy Recapture, Solid Waste Disposal System,
  - Products in Use
    - Timber Products
      - Sawtimber softwood, Sawtimber hardwood, Poles softwood, Poles hardwood, Small roundwood softwood, small roundwood hardwood, etc.
  - Primary Products
    - Softwood Lumber, Softwood Plywood, Mill Residue Pulp, Mill Residue Fuel Unused, etc.
  - End Uses
    - New residential construction (single, multi family, mobile homes) residential upkeep and improvement, new non-residential construction (all except railroads, railroad ties, railcar repair), Manufacturing (household furniture, other furniture, other products), Shipping, Other Uses

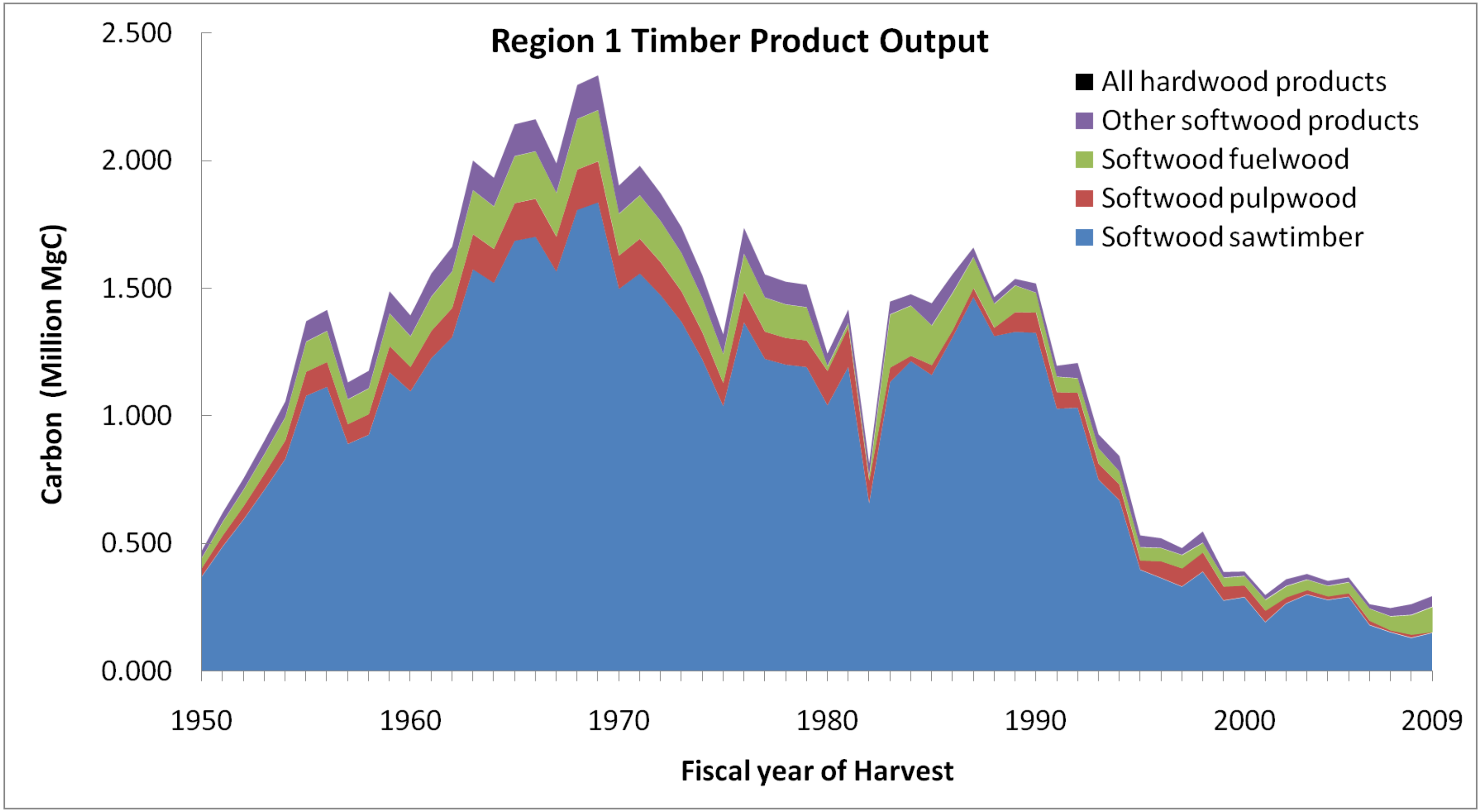


Figure 1. Timber product output for **Region 1**. Output data for 1980 to 2009 was collected from cut/sold reports. Output data for 1950 to 1979 are based on average timber products ratios from 1980 to 2009 applied to total harvest records for Idaho and Montana from Adams et al. 2006.

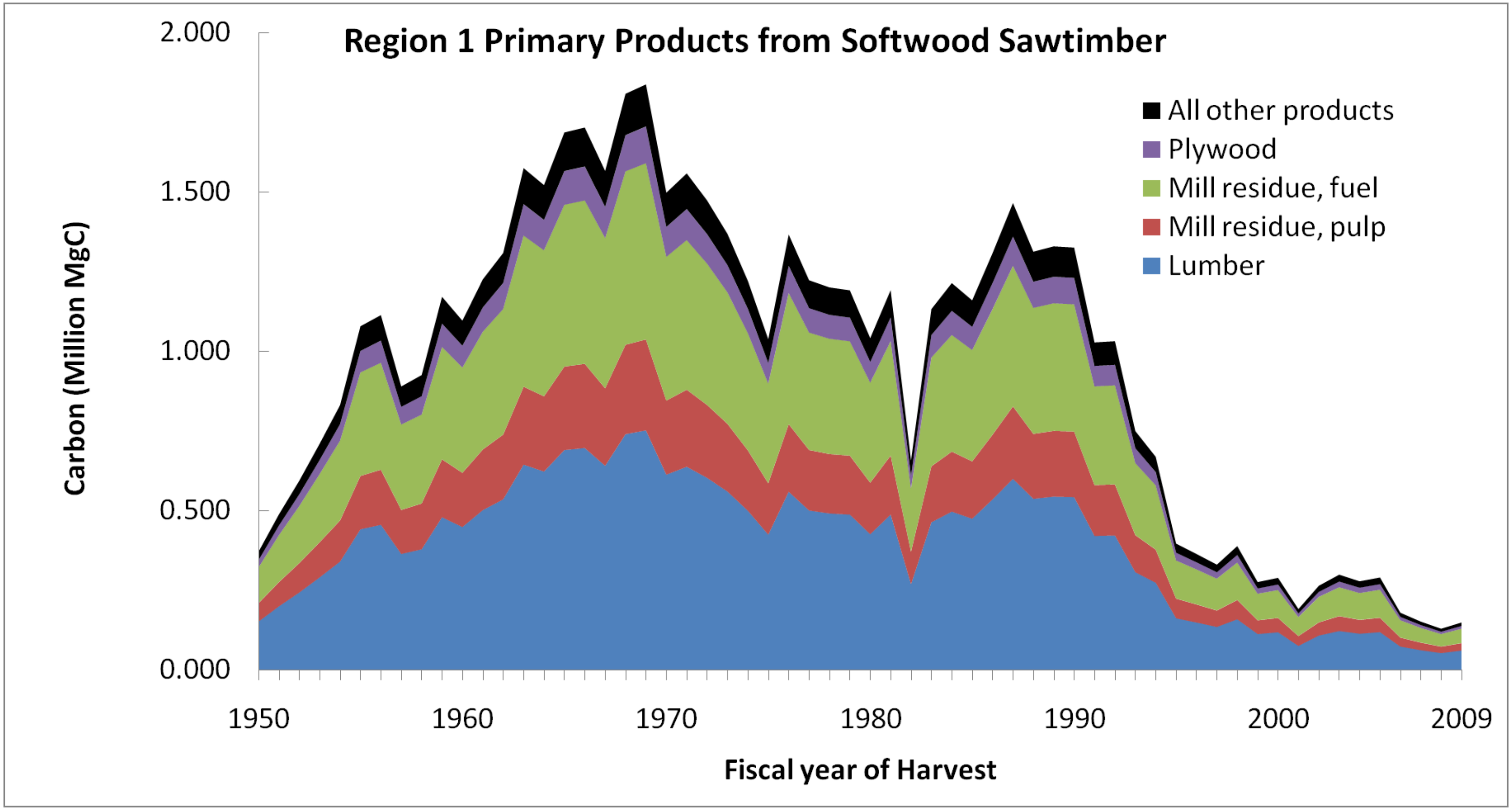


Figure 2. The major primary products produced from softwood sawtimber harvested in **Region 1**. Softwood sawtimber accounts for 77% of the annual harvest, on average, for years 1980 to 2009. Distribution of primary products is based on ratios for 2002 for the Northern Rockies.

Distribution of Timber Products to Primary Wood Products for Regions of the US (Smith et al. 2006).

Table D6.—Fraction of each classification of industrial roundwood according to category as allocated to primary wood products (based on data from 2002)[a]

Region	Category[b] SW/HW	Category[b] SL/PW	Softwood lumber	Hardwood lumber	Softwood plywood	Hardwood plywood[c]	Oriented strandboard	Non-structural panels	Other industrial products	Wood pulp	Fuel and other emissions
Northeast	SW	SL	0.391	0	0.004	0	0	0.020	0.083	0.072	0.431
		PW	0	0	0	0	0.010	0.016	0	0.487	0.487
	HW	SL	0	0.492	0	0.005	0	0.022	0.038	0.058	0.386
		PW	0	0	0	0	0.293	0.007	0	0.350	0.350
North Central	SW	SL	0.378	0	0	0	0	0.049	0.120	0.084	0.370
		PW	0	0	0	0	0.020	0.009	0	0.486	0.486
	HW	SL	0	0.458	0	0.006	0	0.013	0.044	0.064	0.415
		PW	0	0	0	0	0.361	0.009	0	0.315	0.315
Pacific Northwest, East	SW	All	0.422	0	0.069	0	0	0.001	0.001	0.144	0.363
Pacific Northwest, West	SW	SL	0.455	0	0.089	0	0	0.009	0.073	0.114	0.260
		PW	0	0	0	0	0	0	0	0.500	0.500
	HW	All	0	0.160	0	0.140	0	0.002	0	0.229	0.469
Pacific Southwest	SW	All	0.454	0	0	0	0	0.040	0.036	0.145	0.325
Rocky Mountain	SW	All	0.402	0	0.054	0	0	0.033	0.062	0.153	0.296
Southeast	SW	SL	0.350	0	0.076	0	0	0.027	0.054	0.129	0.364
		PW	0	0	0	0	0.103	0.004	0	0.447	0.447
	HW	SL	0	0.455	0	0.006	0	0.049	0.012	0.087	0.391
		PW	0	0	0	0	0.180	0.002	0	0.409	0.409
South Central	SW	SL	0.324	0	0.130	0	0	0.019	0.023	0.133	0.371
		PW	0	0	0	0	0.135	0.006	0	0.430	0.430
	HW	SL	0	0.434	0	0.023	0	0.025	0.003	0.102	0.413
		PW	0	0	0	0	0.160	0.001	0	0.419	0.419
West[d]	HW	All	0	0.039	0	0.301	0	0.015	0.066	0.147	0.432

[a]Data based on Adams and others (2006).

[b]SW/HW=Softwood/Hardwood, SL/PW=Saw log/Pulpwood. Saw log includes veneer logs.

[c]Hardwood plywood fractions are pooled with nonstructural panels when allocating roundwood to the primary products listed in Tables 8 and 9.

[d]West includes hardwoods in Pacific Northwest, East; Pacific Southwest; Rocky Mountain, North; and Rocky Mountain, South.

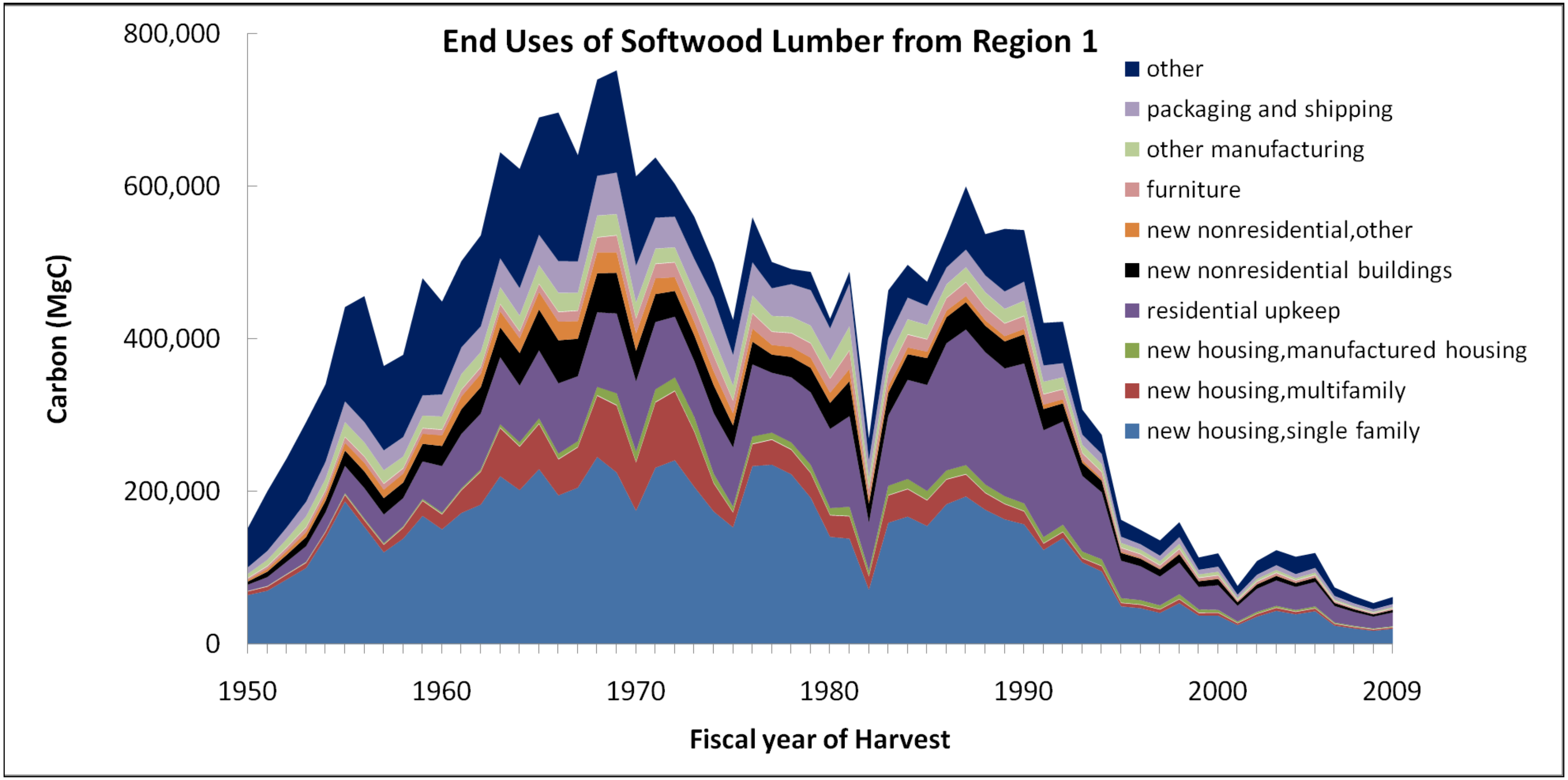


Figure 3. Distribution of end uses for softwood lumber from **Region 1**. Softwood lumber is the largest primary product carbon pool. The distribution of lumber production to end uses is based on data for 1950 to 2006 from McKeever 2009.

Calculating Persistence and Disposition

For each of the 203 different possible end uses from the Region's HWP (e.g., softwood lumber/new housing/single family), for each vintage year, the amount of carbon remaining in use at each inventory year is calculated based on the product half-life and the number of years that have passed between the year of harvest and the inventory year. The half-life value expresses the decay rate at which carbon in the products in use category passes into the discarded category, representing the transition between the two pools. The carbon remaining in HWP in use in a given inventory year is calculated for each vintage year end use based on a standard decay formula:

$$N_t = N_0 \exp(-t\ln(2)/t_{1/2})$$

where N_t is the amount of carbon remaining in use in inventory year t, N_0 is the amount of carbon in the end use category in the vintage year of harvest, t is the number of years since harvest, $t_{1/2}$ is the half-life of carbon in that end use, and exp is notation for the exponential function. In our calculations, the starting amount (N_0, at n=0) is adjusted downward by 8% to reflect a loss when placed in use, which is assumed to enter the discarded carbon category. This loss in use accounts for waste when primary products (e.g. softwood lumber) are put into specific end uses (e.g. new single family residential housing), and this waste is immediately distributed to the discarded products category. Fuelwood products are assumed to have full emissions with energy capture in the year they were produced.

End use or product	Half life in years	Loss when placed in use	Half life Woodcarb II	Half life Woodcarb I	Loss when placed in use Woodcarb II
New residential construction					
Single family	83.90697	0.08	83.9	100	0.08
Multifamily	51.29981	0.08	51.3	70	0.08
Mobile homes	38.02841	0.08	38.0	12	0.08
Residential upkeep & improvement	24.88536	0.08	24.9	30	0.08
New nonresidential construction					
All ex. railroads	38.02841	0.08	38.0	67	0.08
Railroad ties	38.02841	0.08	38.0	12	0.08
Railcar repair	38.02841	0.08	38.0	12	0.08
Manufacturing					
Household furniture	38.02841	0.08	38.0	30	0.08
Commercial furniture	38.02841	0.08	38	30	0.08
Other products	38.02841	0.08	38.0	12	0.08
Shipping					
Wooden containers	38.02841	0.08	38.0	6	0.08
Pallets	38.02841	0.08	38.0	6	0.08
Dunnage etc	38.02841	0.08	38.0	6	0.08
Other uses for lumber and panels	38.02841	0.08	38.0	12	0.08
Miscellaneous products	38.02841	0.08	38.0	12	0.08
Solid wood exports	38.02841	0.08	38.0	12	0.08
Paper	2.530873	0	2.53	2	

SOURCE: Skog and Nicholson (1998); Row and Phelps (1996)

Uncertainty Analysis

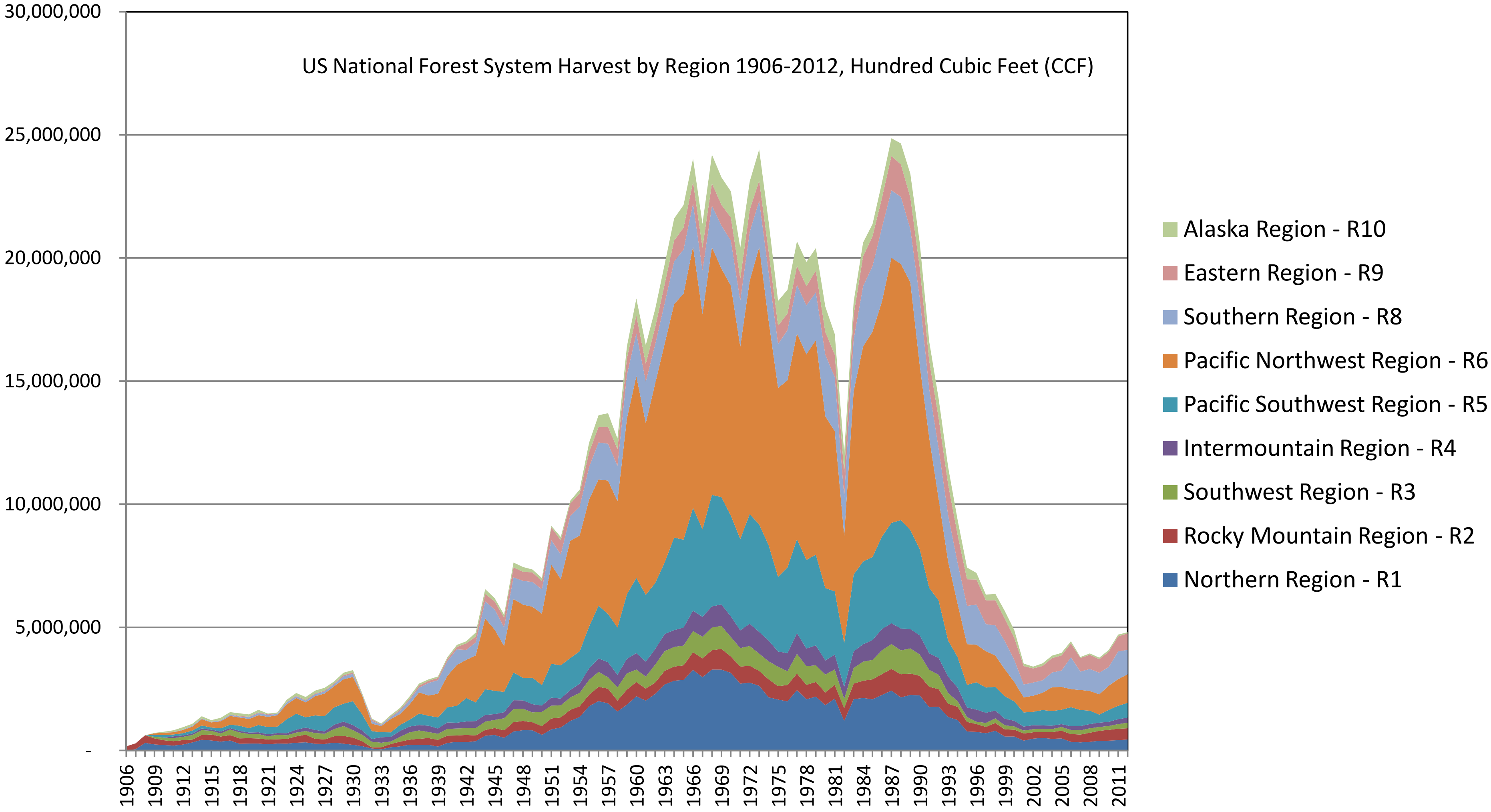
- Approach
- Factors Table
- Results
- Future exploration

PNW - Region 6 Example

Source of Uncertainty	Range of distribution	Years
Reported harvest in ccf	±30%	start to 1945
	±20%	1946 to 1979
	±15%	1980 to end
Timber product ratios	±30%	start to 1945
	±20%	1946 to 1979
	±15%	1980 to end
Primary product ratios	±30%	start to 1945
	±20%	1946 to 1979
	±15%	1980 to end
Conversion factors, ccf to MgC	±5%	all years
End use product ratios	±15%	all years
Product half lives	±15%	all years
Discarded disposition ratios (paper)	±15%	all years
Discarded disposition ratios (wood)	±15%	all years
Landfill decay limits (paper)	±15%	all years
Landfill decay limits (wood)	±15%	all years
Landfill half-lives (paper)	±15%	all years
Landfill half-lives (wood)	±15%	all years
Dump half-lives (paper)	±15%	all years
Dump half-lives (wood)	±15%	all years
Recovered half-lives (paper)	±15%	all years
Recovered half-lives (wood)	±15%	all years
Burned with energy capture ratio	±15%	all years

Uncertainty Analyses

- The probability distributions of these random variables were developed based on estimates in Skog (2008) and on professional judgment, and are assumed to be triangular and symmetric. A triangular error distribution was selected because without additional empirical information, we reasonably assume the error distribution to be symmetric with greater likelihood of values being centered in between the limits of the distribution than at one or both of the limits of the distribution. In addition, we can reasonably assign values to the limits. The distributions are assumed to be independent of one another.
- The effect of uncertainty in these variables on HWP carbon storage was evaluated using Monte Carlo simulation. For each simulation, a mean value and 90% confidence intervals are the results of 3,000 iterations performed to reach a stable standard deviation in the mean (Stockmann et al. 2012). In each iteration, HWP carbon stocks are calculated using values for variables drawn at random from the established distributions. Using thousands of draws, we produce a simulation mean and a distribution of values that can be used to establish the confidence intervals shown in the tables. These confidence intervals show the range of values in which 90% of all values are expected to fall.

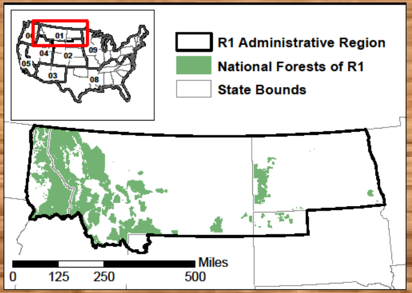


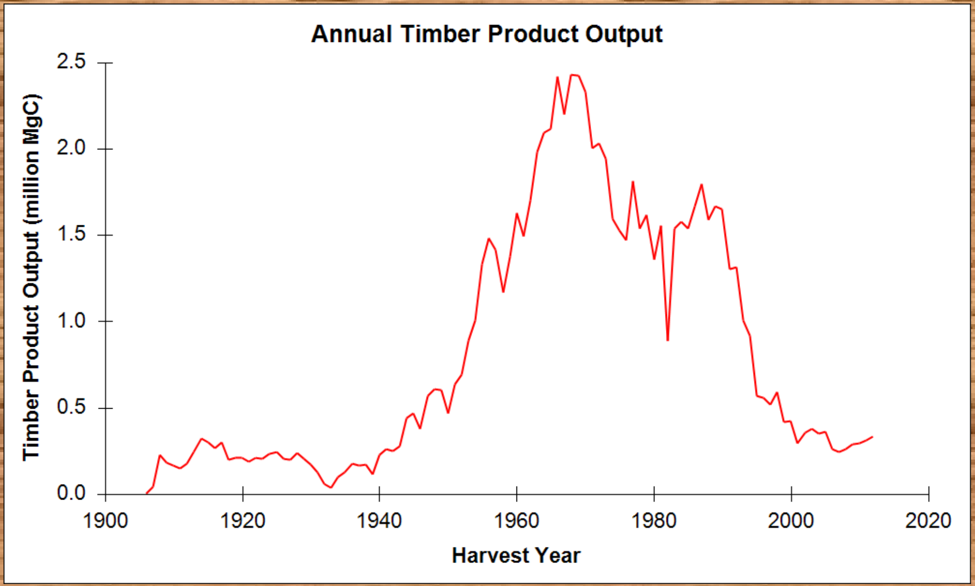
US National Forest System Harvest by Region 1906-2012, Hundred Cubic Feet (CCF)
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
1906
1909
1912
1915
1918
1921
1924
1927
1930
1933
1936
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Alaska Region - R10
Eastern Region - R9
Southern Region - R8
Pacific Northwest Region - R6
Pacific Southwest Region - R5
Intermountain Region - R4
Southwest Region - R3
Rocky Mountain Region - R2
Northern Region - R1

Tools

- National Harvest Dataset
- HWP Website

Northern Region (R1) northern Idaho, Montana



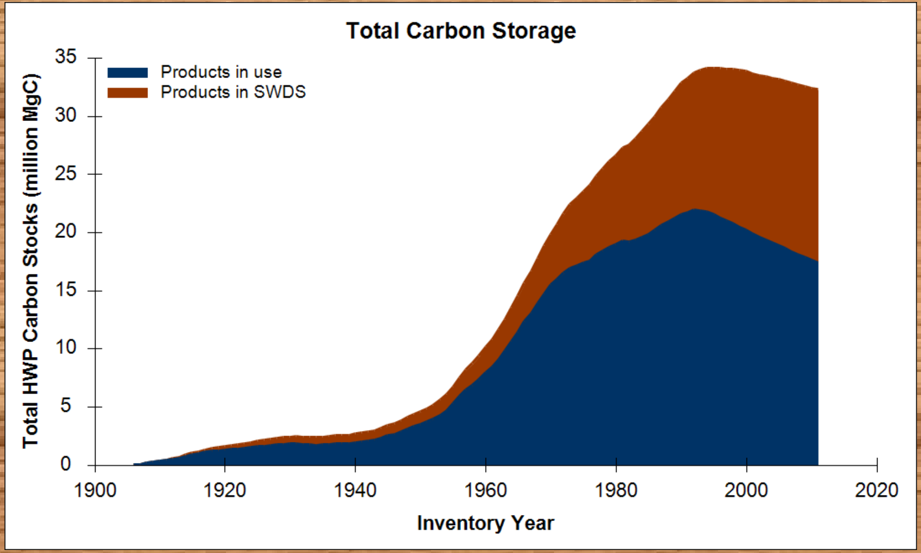


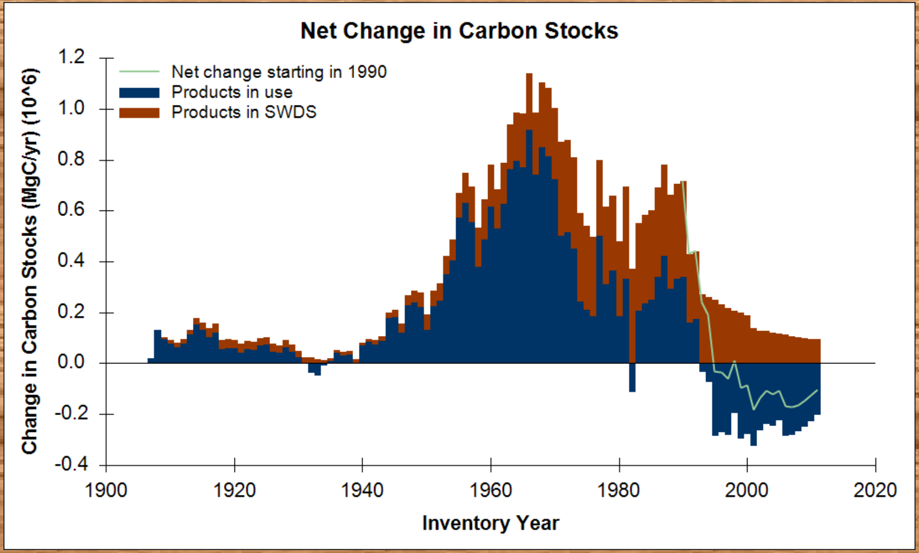
Peak Harvest:
2,420,000 MgC
Year: 1968

Peak Storage:
34,100,000 MgC
Year: 1995

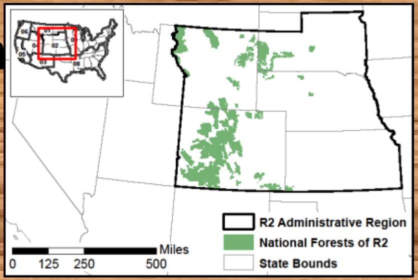
Biggest Positive Net Annual Change:
1,140,000 MgC
Year: 1967

Biggest Negative Net Annual Change:
185,000 MgC
Year: 2002



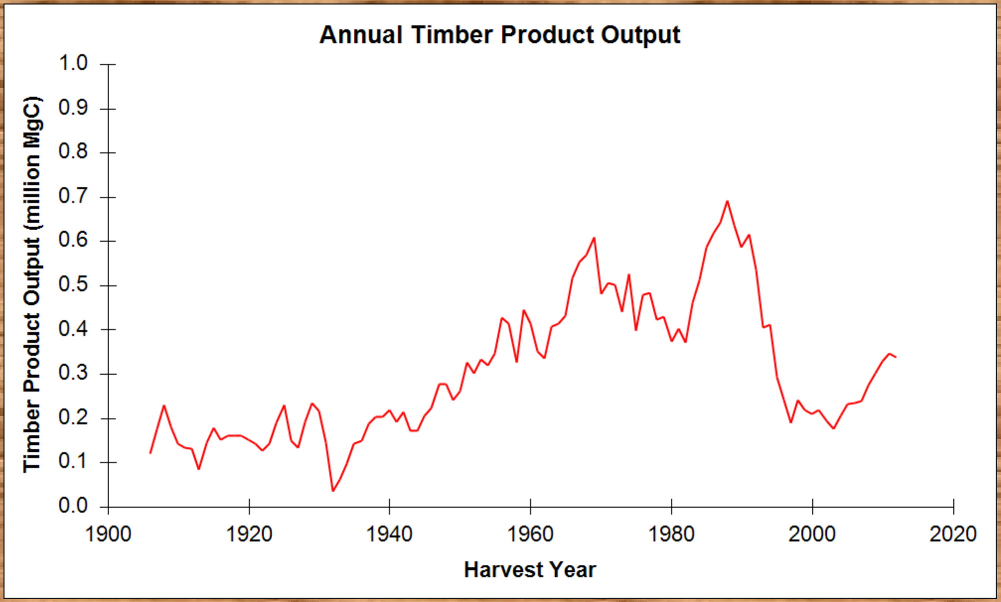


Rocky Mountain Region (R2) Colorado, Wyoming, South



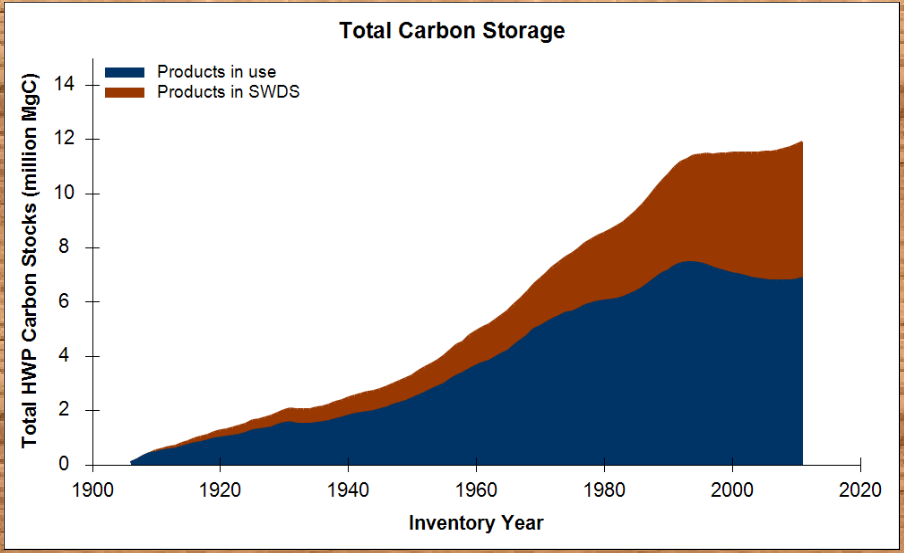
Peak Harvest:
690,000+ MgC
Year: 1988

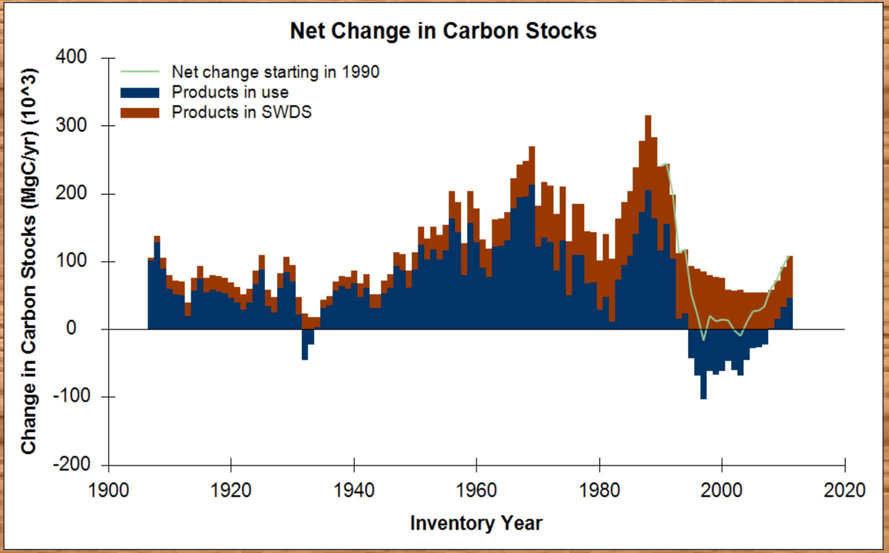
Peak Storage:
12,006,648 MgC
Year: 2013



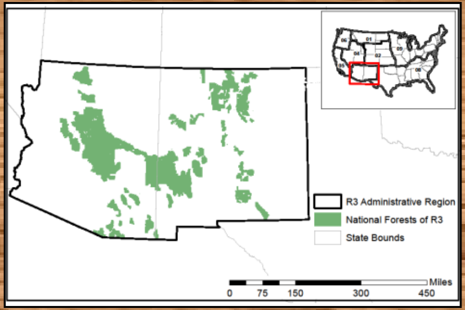
Biggest Positive Net Annual Change: 270,000 MgC
Year: 1970

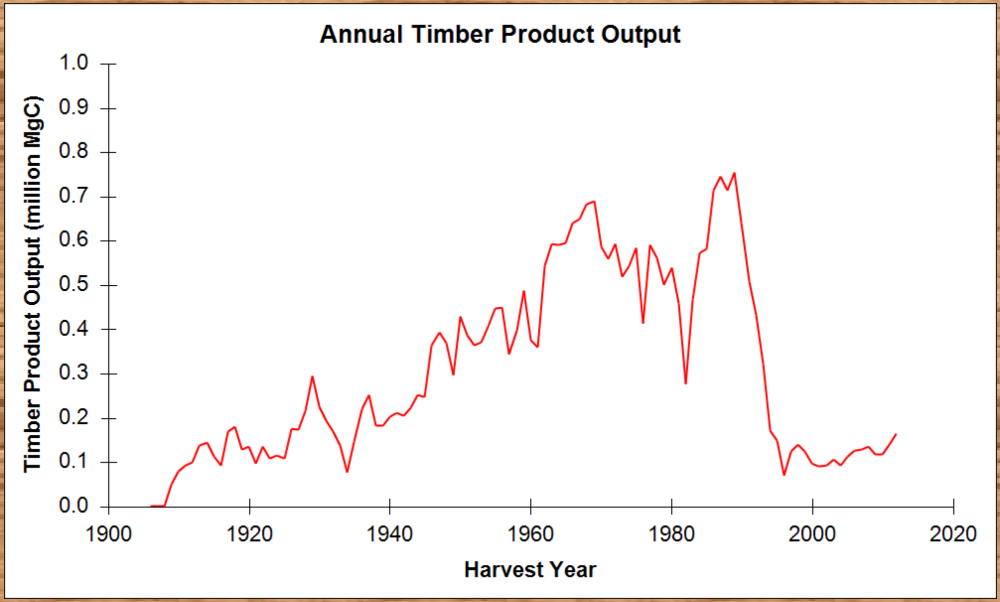
Biggest Negative Net Annual Change: 16,000 MgC
Year: 1998





Southwest Region (R3) Arizona, New Mexico



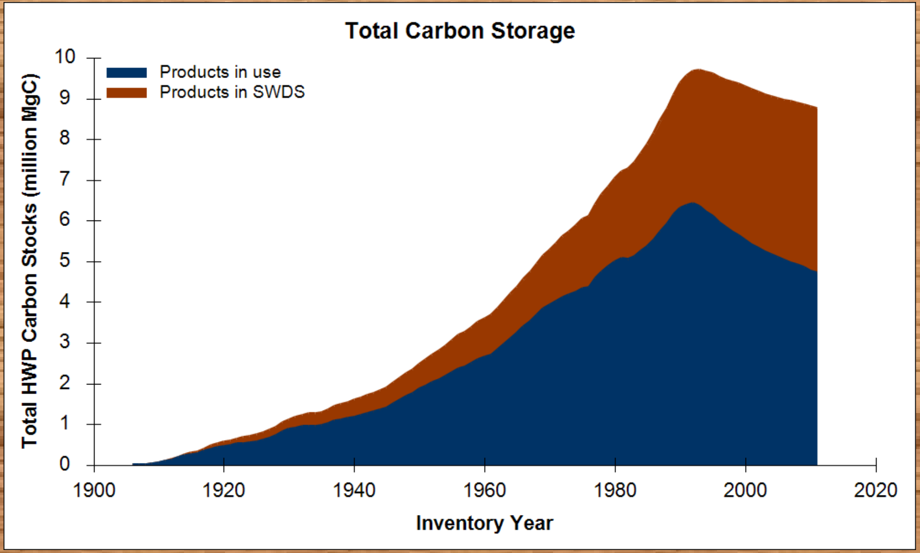


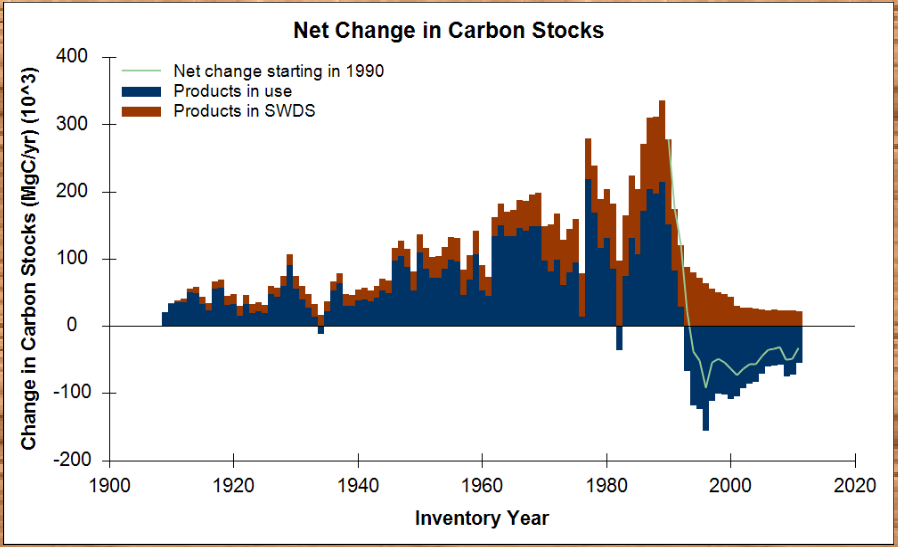
Peak Harvest: 590,000 MgC
Year: 1972

Peak Storage: 9,700,000 MgC
Year: 1994

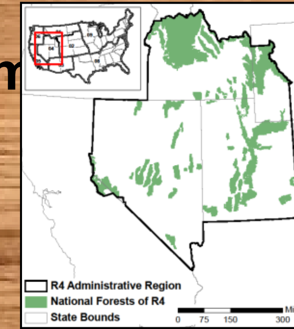
Biggest Positive Net Annual Change: 335,000 MgC
Year: 1990

Biggest Negative Net Annual Change: 57,000 MgC
Year: 2004



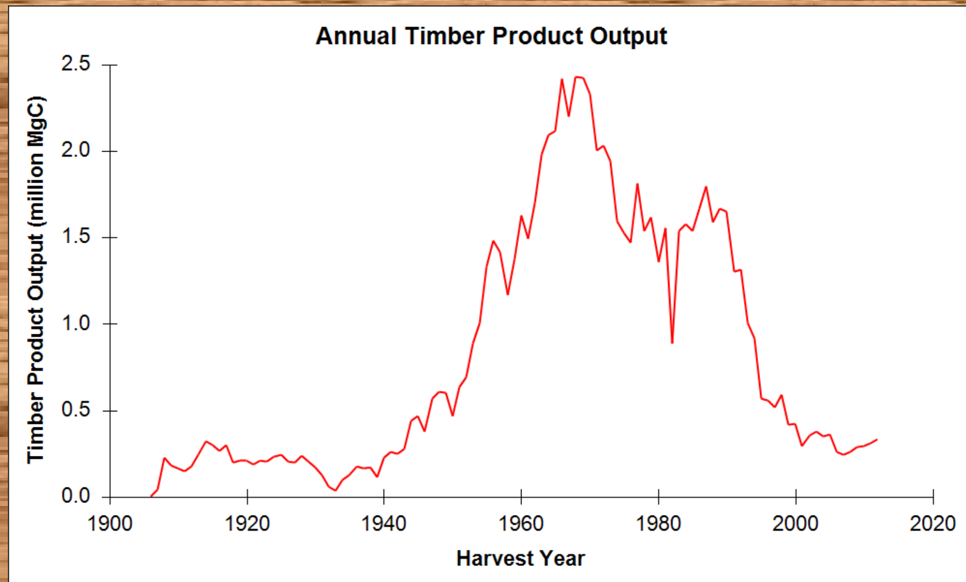


Intermountain Region (R4) Nevada, Utah, S. Idaho, SW Wyom



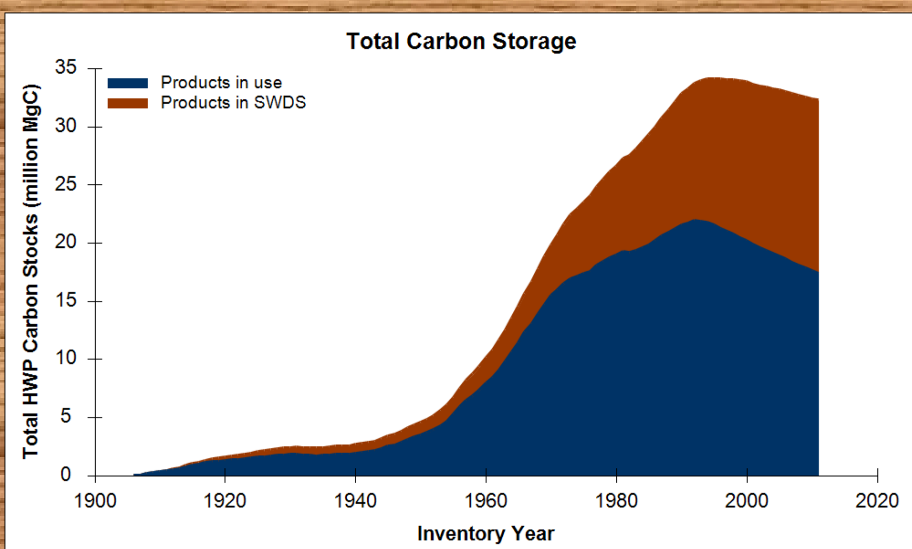
Peak Harvest:
658,000+ MgC
Year: 1972

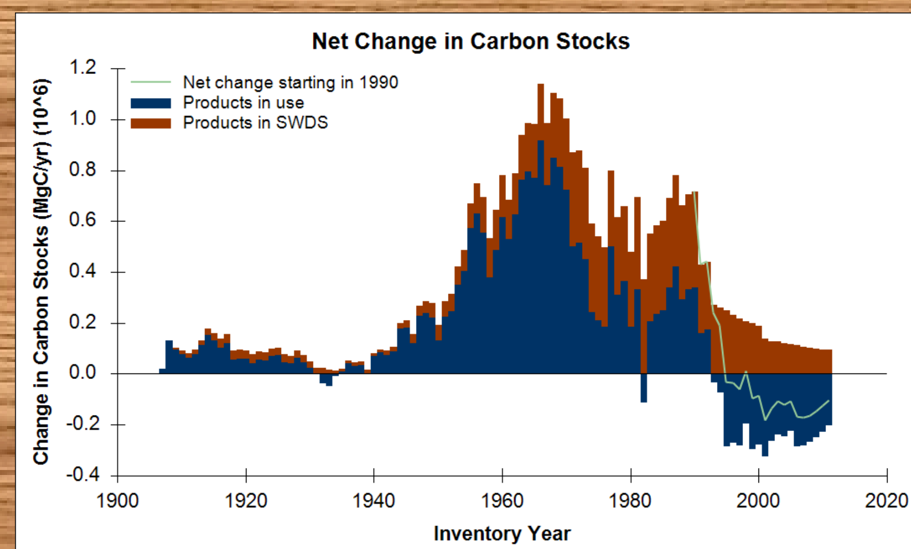
Peak Storage:
9,500,000 MgC
Year: 2000



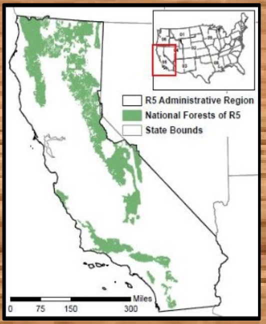
Biggest Positive Net Annual Change: 308,000 MgC
Year: 1978

Biggest Negative Net Annual Change: 61,000 MgC
Year: 2004



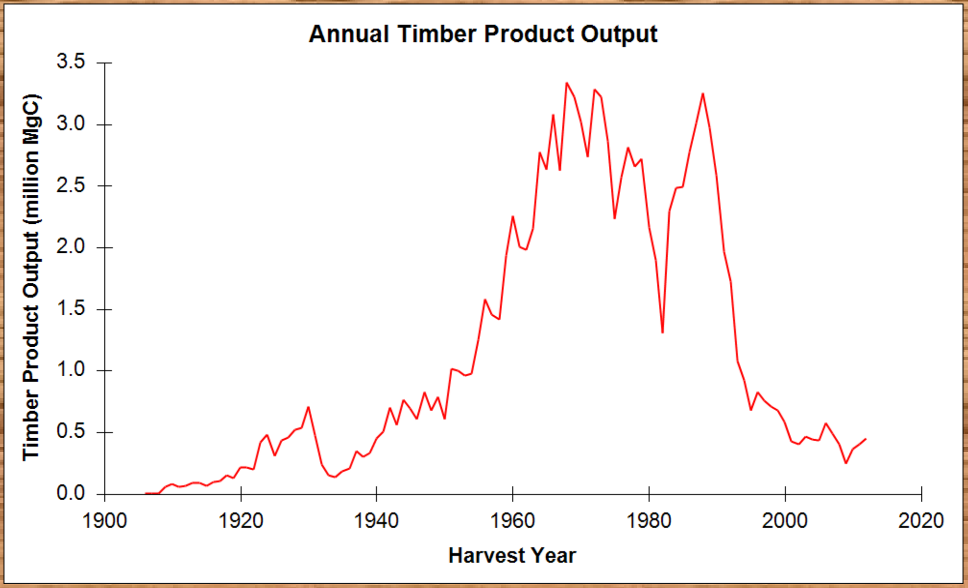


Pacific Southwest Region (R5) California



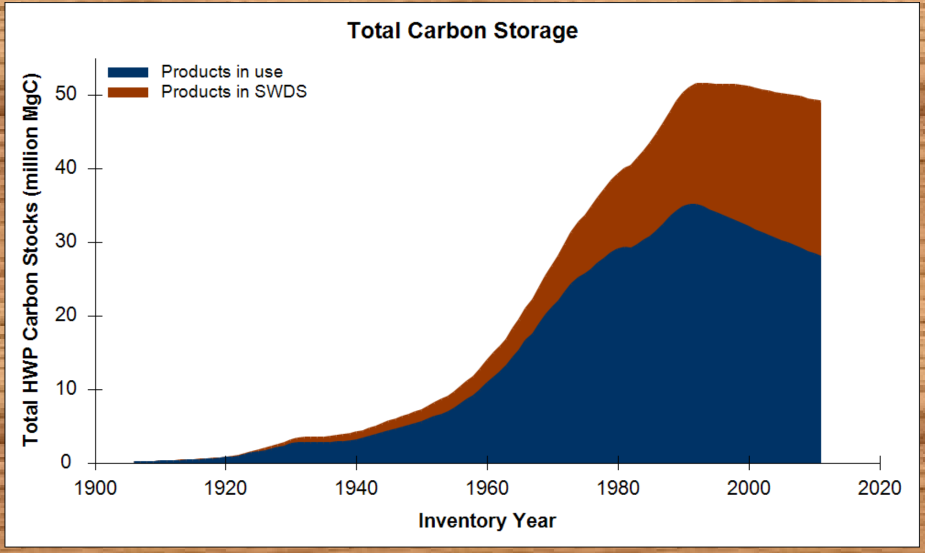
Peak Harvest:
3,300,000 MgC
Year: 1968

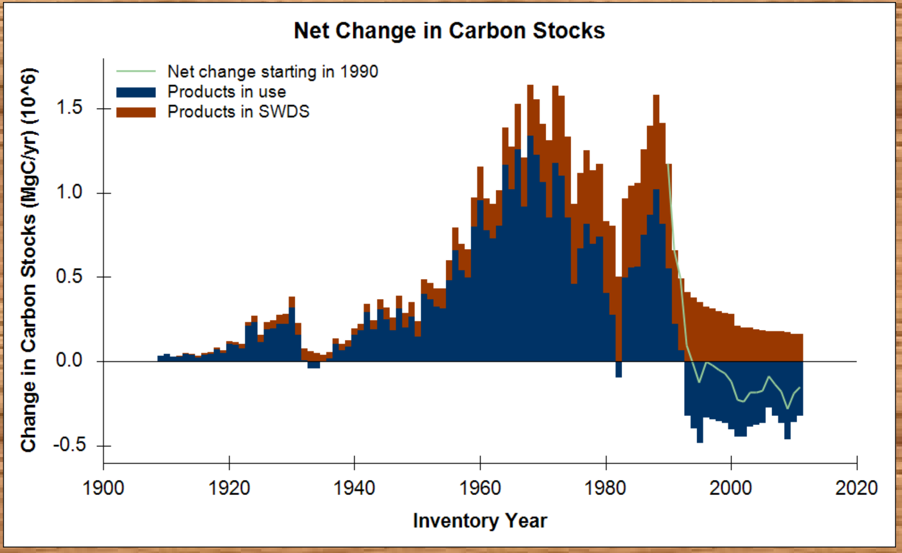
Peak Storage:
51,000,000 MgC
Year: 1994



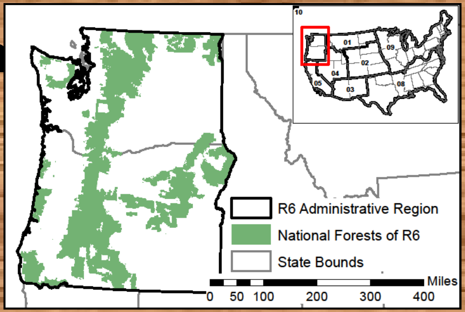
Biggest Positive Net Annual Change:
1,640,000 MgC
Year: 1973

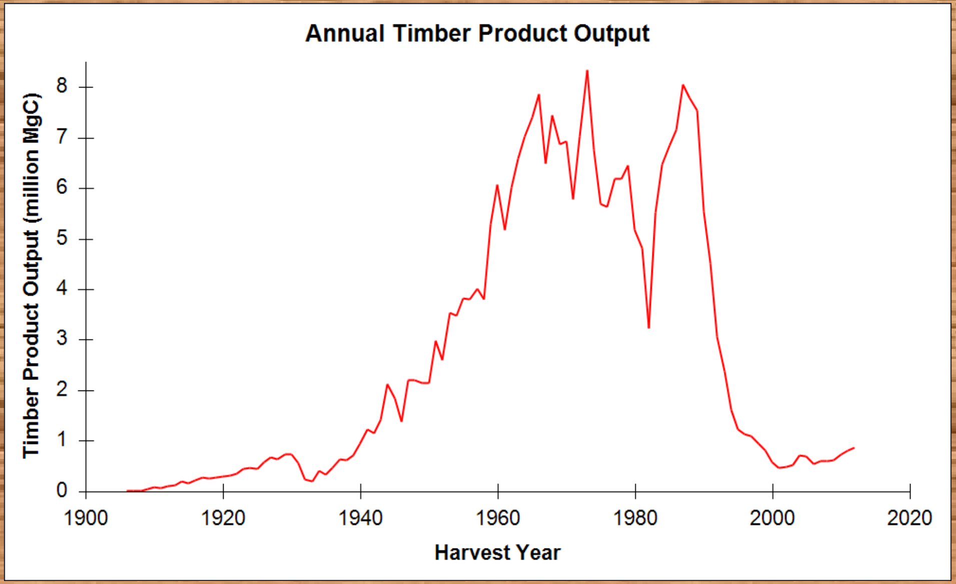
Biggest Negative Net Annual Change:
280,000 MgC
Year: 2010





Pacific Northwest Region (R6) Oregon, Washington



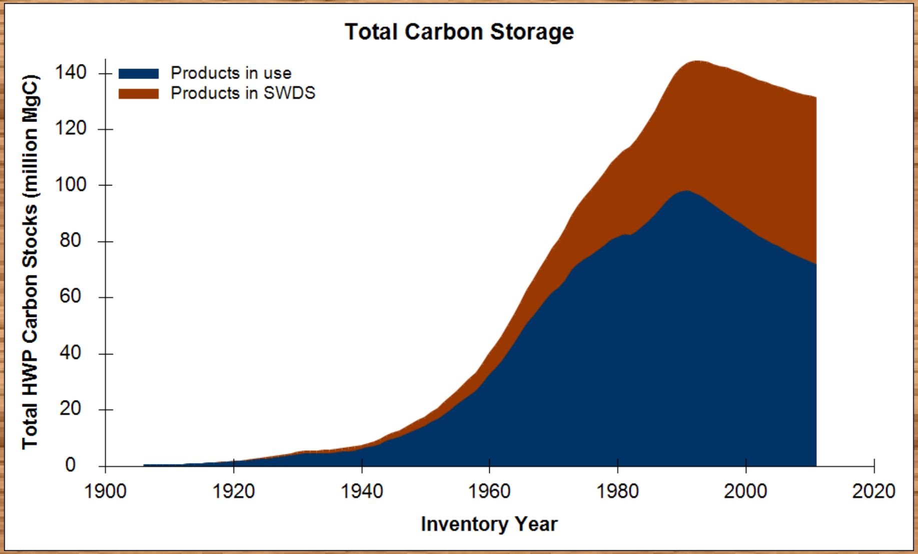


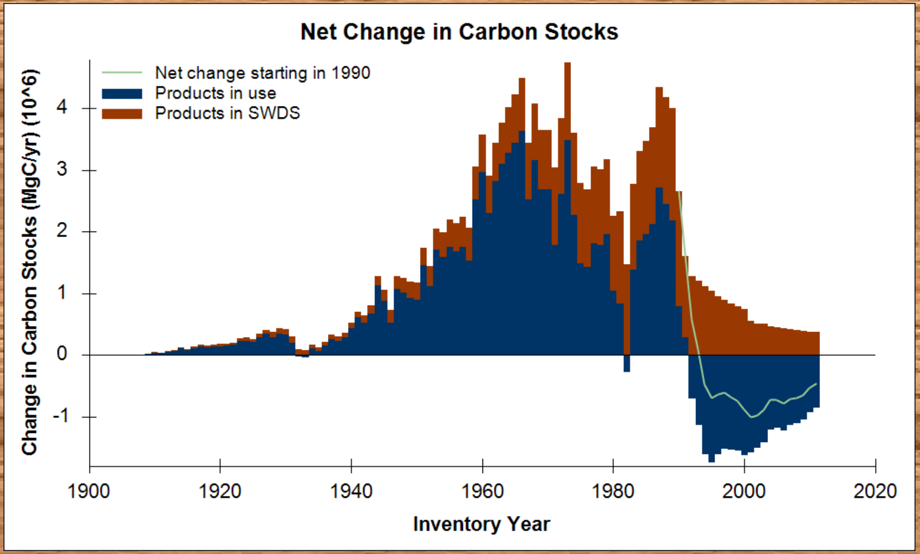
Peak Harvest:
8,300,000 MgC
Year: 1973

Peak Storage:
144,000,000 MgC
Year: 1994

Biggest Positive Net Annual Change:
4,750,000 MgC
Year: 1974

Biggest Negative Net Annual Change:
1,000,000 MgC
Year: 2002

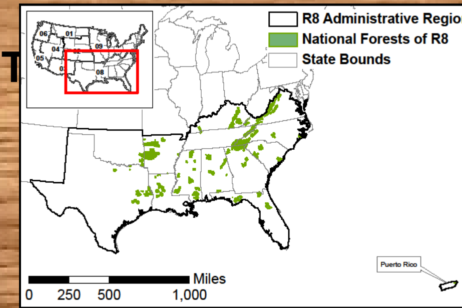




Uncertainty Results - PNW - Region 6 Example

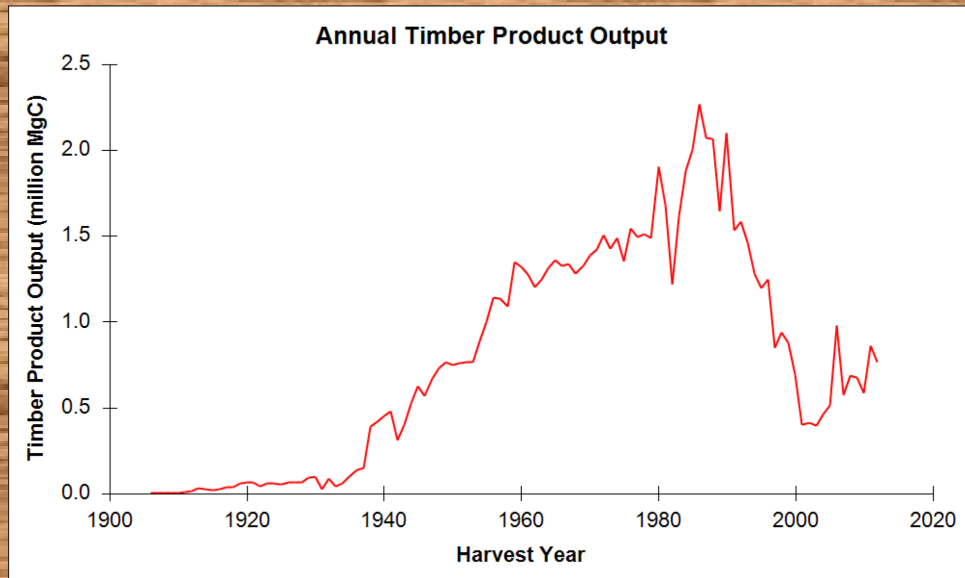
Inventory year	Simulation Mean (MgC)	90% Confidence interval	
		Lower limit (MgC)	Upper limit (MgC)
1910	31,092	30,973	31,210
1920	1,118,800	1,117,312	1,120,287
1930	4,093,311	4,088,793	4,097,829
1940	6,459,954	6,453,999	6,465,908
1950	15,987,116	15,973,344	16,000,889
1960	36,119,950	36,093,452	36,146,449
1970	73,717,506	73,666,543	73,768,469
1980	107,294,394	107,226,173	107,362,615
1990	138,899,539	138,820,659	138,978,420
1995	143,343,500	143,263,436	143,423,563
2000	139,955,865	139,876,951	140,034,779
2005	135,445,580	135,367,737	135,523,423
2006	134,719,081	134,641,338	134,796,823
2007	133,934,274	133,856,605	134,011,944
2008	133,221,772	133,144,185	133,299,360
2009	132,525,019	132,447,470	132,602,568
2010	131,873,807	131,796,282	131,951,332
2011	131,339,883	131,262,348	131,417,417
2012	130,873,955	130,796,380	130,951,531
2013	130,470,976	130,393,318	130,548,634

Southern Region (R8) AL, AR, GA, FL, KY, LA, MS, NC, OK, SC, T



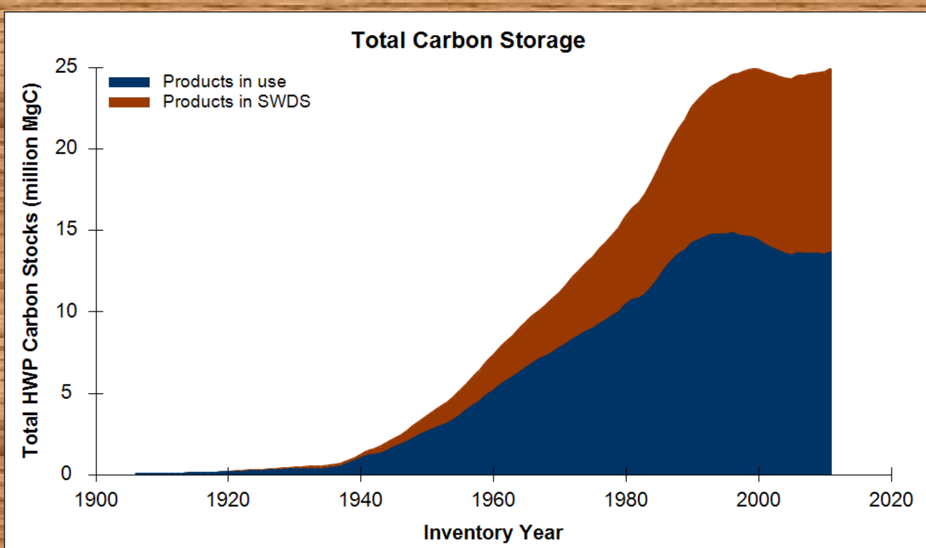
Peak Harvest:
2,200,000 MgC
Year: 1986

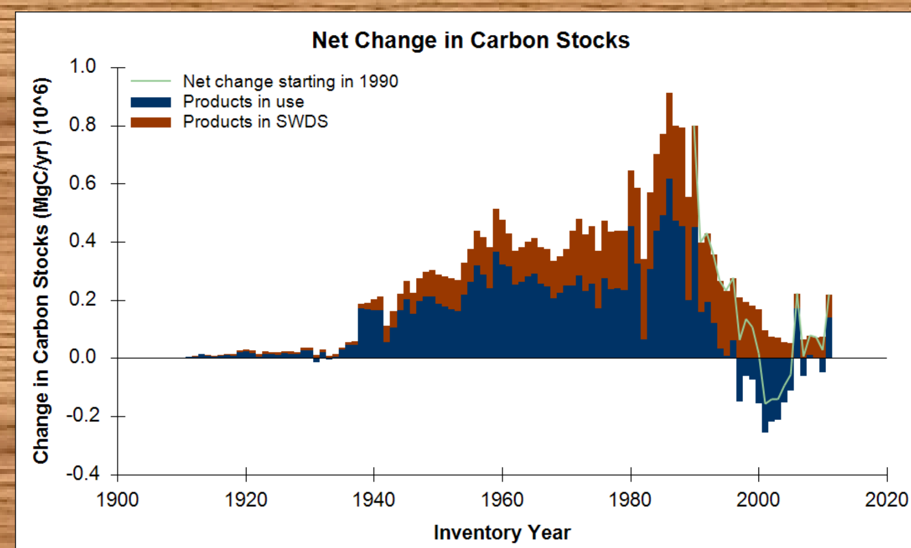
Peak Storage:
25,000,000 MgC
Year: 2013



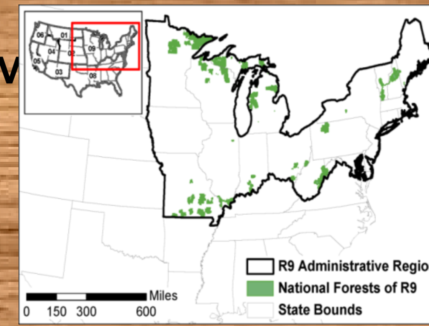
Biggest Positive Net Annual Change: 914,000 MgC
Year: 1987

Biggest Negative Net Annual Change: 142,000 MgC
Year: 2004



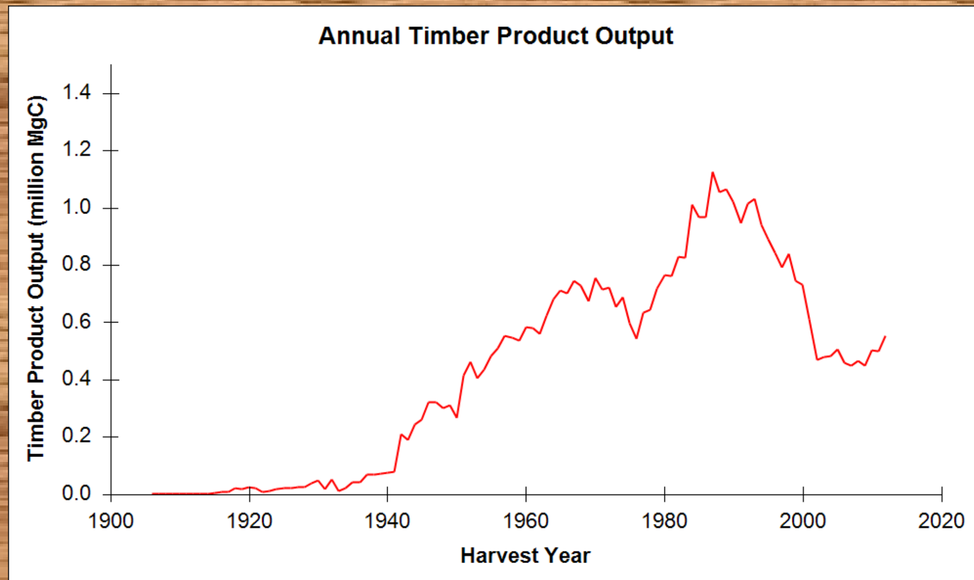


Eastern Region (R9) IA, IL, IN, ME, MI, MN, MO, NH, NY, OH, PA, WI, V



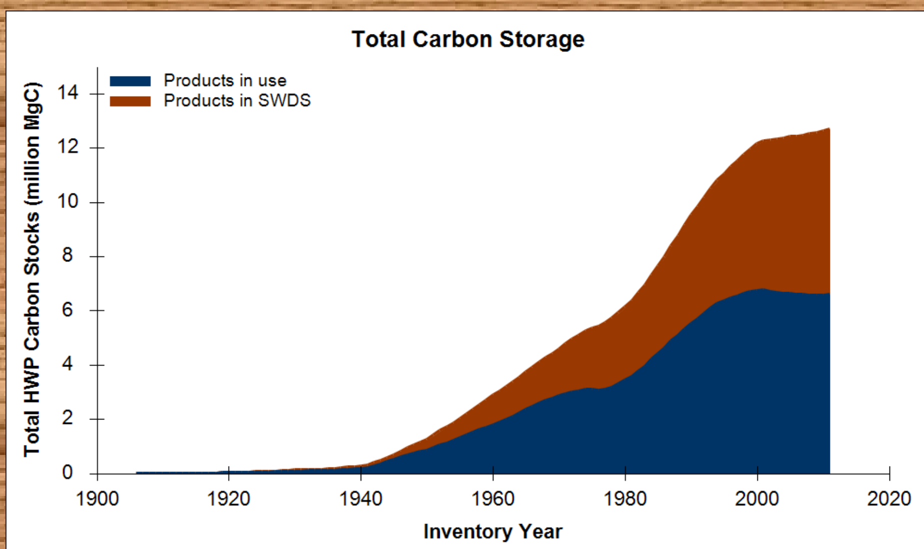
Peak Harvest:
1,100,000 MgC
Year: 1987

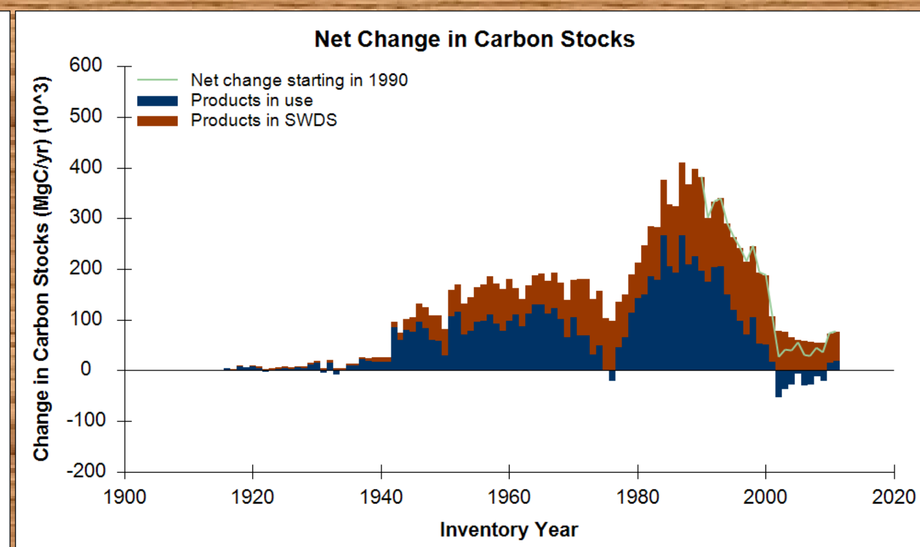
Peak Storage:
12,820,000 MgC
Year: 2013



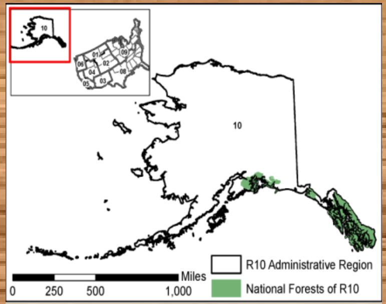
Biggest Positive Net Annual Change: 410,000 MgC
Year: 1988

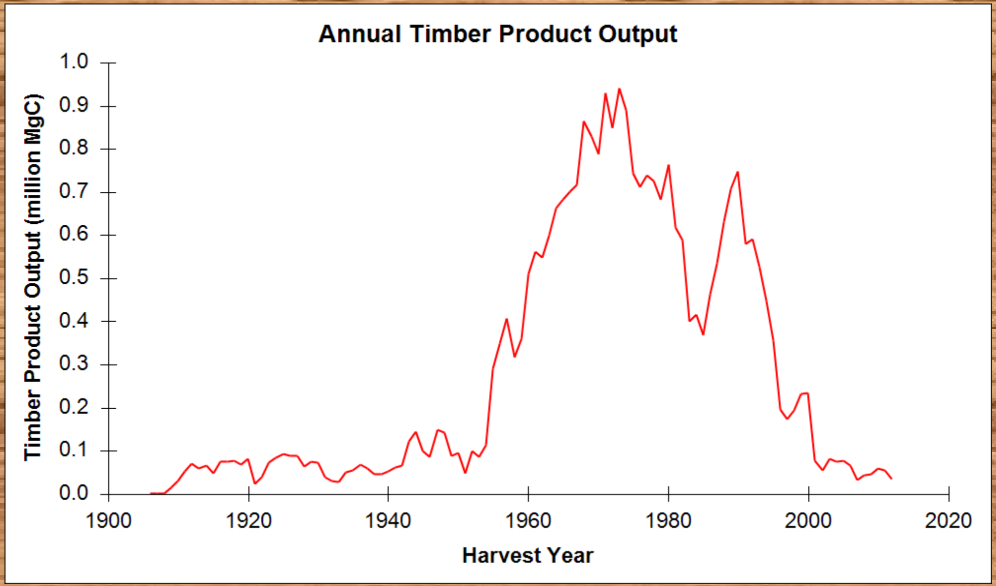
Biggest Negative Net Annual Change:
Not yet*





Alaska Region (R10) Alaska



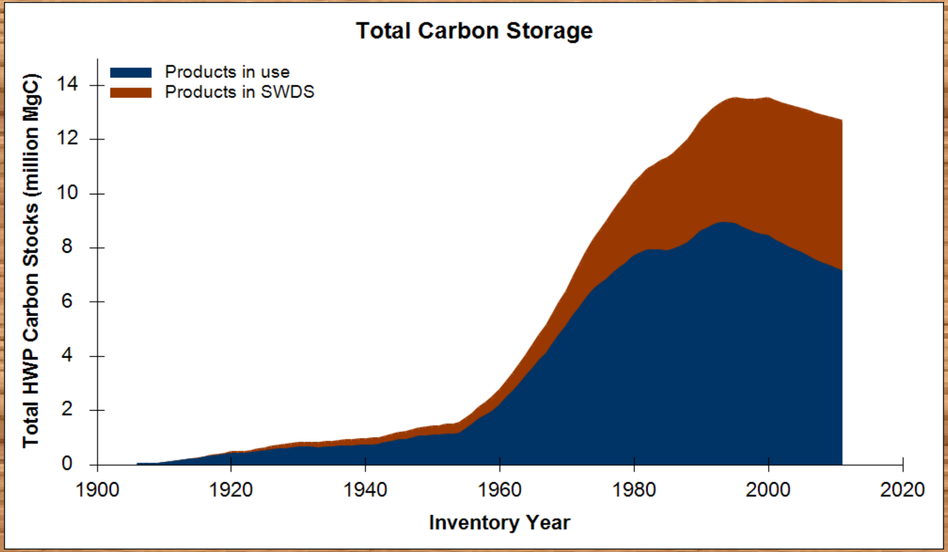


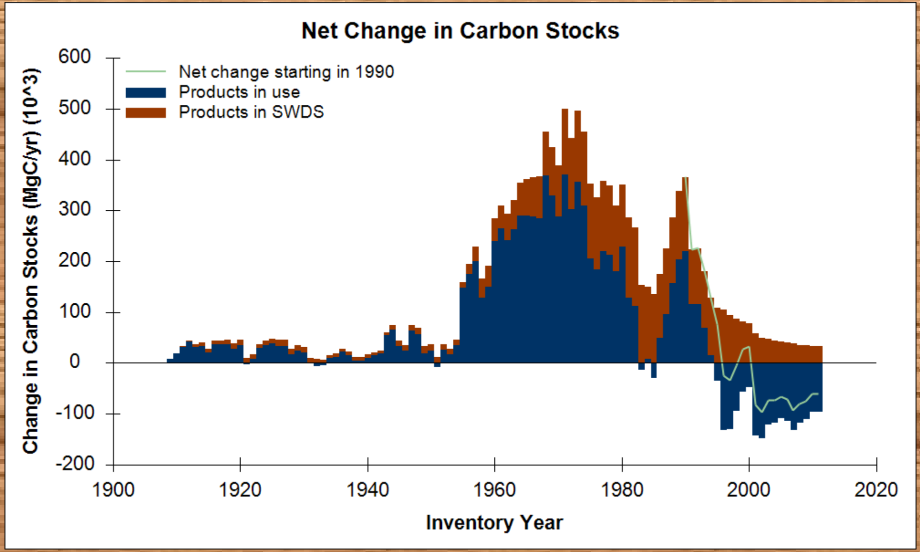
Peak Harvest:
940,000 MgC
Year: 1973

Peak Storage:
13,500,000 MgC
Year: 1996

Biggest Positive Net Annual Change: 500,000 MgC
Year: 1972

Biggest Negative Net Annual Change: 98,000 MgC
Year: 2003



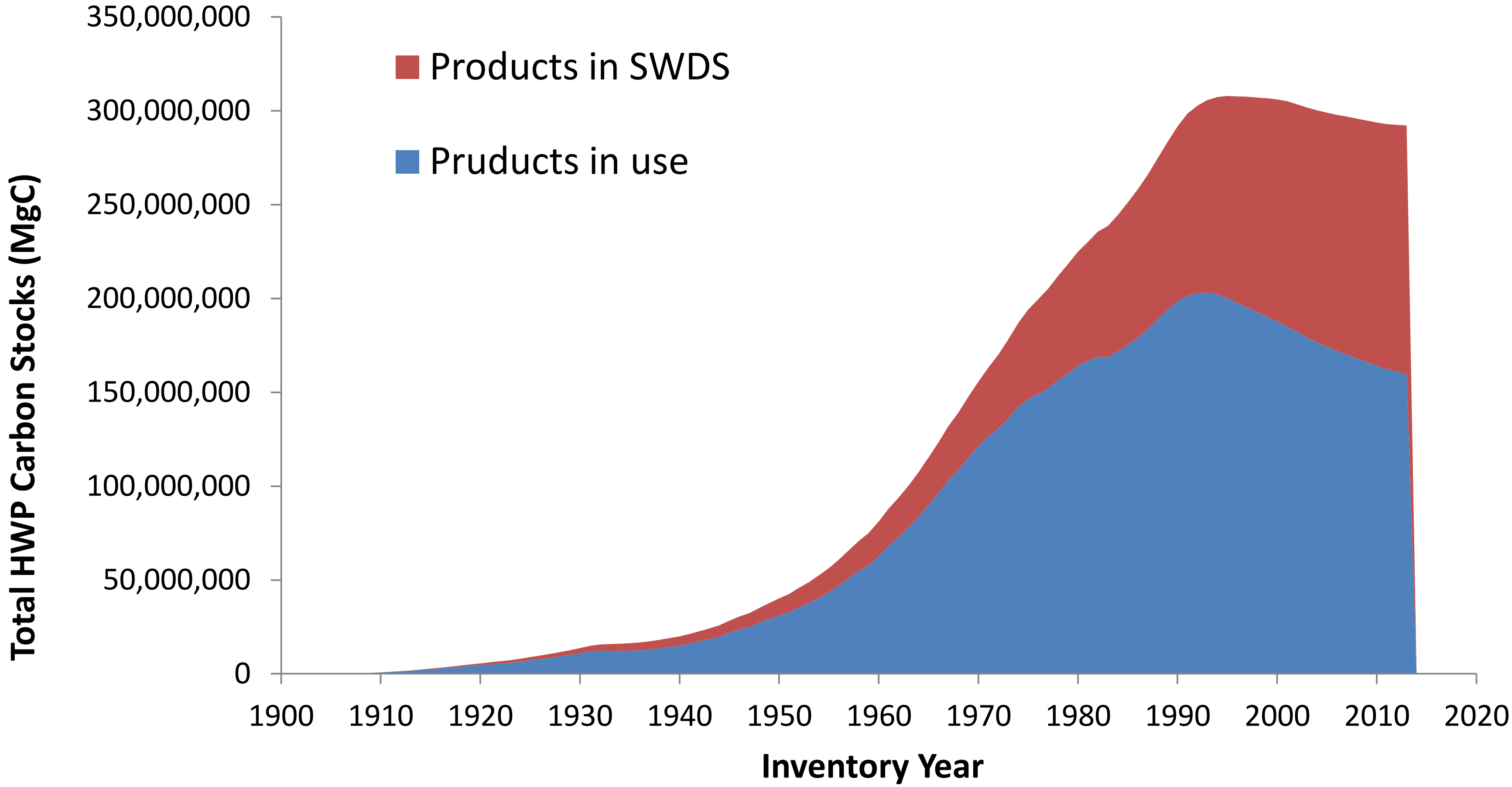


NFS Region	Peak Harvest (TgC) /(Year)	Peak HWP Carbon Storage (TgC) / (Year)	Peak Positive Net Annual Stock Change (TgC) / (Year)	Peak Negative Net Annual Stock Change (TgC) /(Year)
R1- Northern	2.42 (1968)	34.1 (1995)	1.14 (1967)	0.185 (2002)
R2-Rocky Mountain	0.69 (1988)	12.1 (2013)	0.270 (1970)	0.016 (1998)
R3-Southwest	0.59 (1972)	9.7 (1994)	0.335 (1990)	0.057 (2004)
R4-Intermountain	0.66 (1972)	9.5 (2000)	0.308 (1978)	0.061 (2004)
R5-PSW	3.3 (1968)	51.0 (1994)	1.64 (1973)	0.280 (2010)
R6-PNW	8.3 (1973)	144.0 (1994)	4.75 (1974)	1.0 (2002)
R-8 Southern	2.2 (1986)	25.0 (2013)	0.914 (1987)	0.142 (2004)
R-9 Eastern	1.1 (1987)	12.82 (2013)	0.410 (1998)	Not Yet
R10- Alaska	0.94 (1973)	13.5 (1996)	0.500 (1972)	0.098 (2003)
National Forest System Total	(1987)	307.79 (1995)	8.79 (1988)	1.69 (2003)

What explains the differences?

- Harvest volumes, especially in recent years
- Timber products – Hardwood v Softwood
- Wood Product Types

National Storage Summary Figures



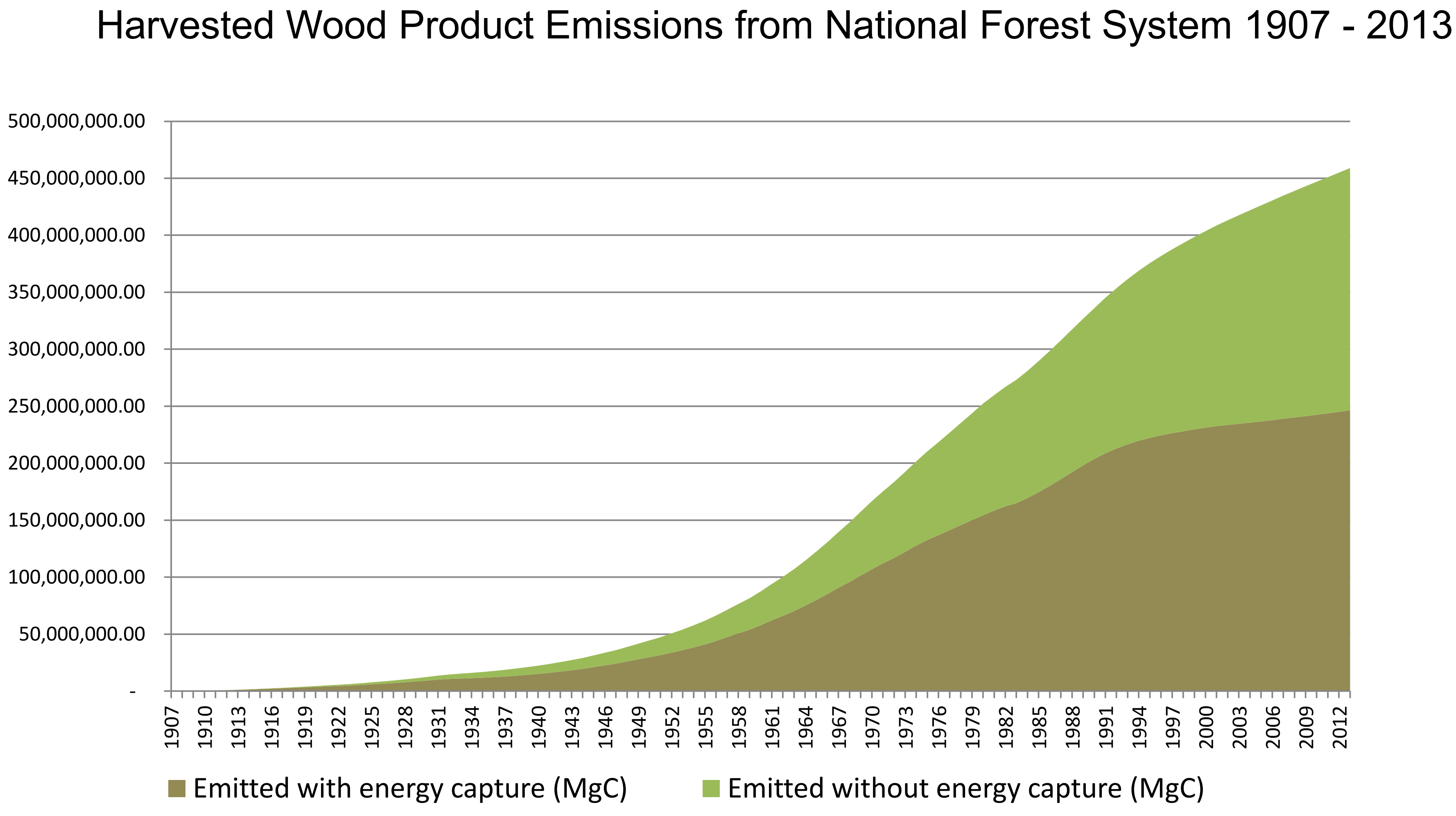
Storage is decreasing because harvest has fallen, but look how much carbon is still being stored, but still less than 1% of all Forest Sector C storage.

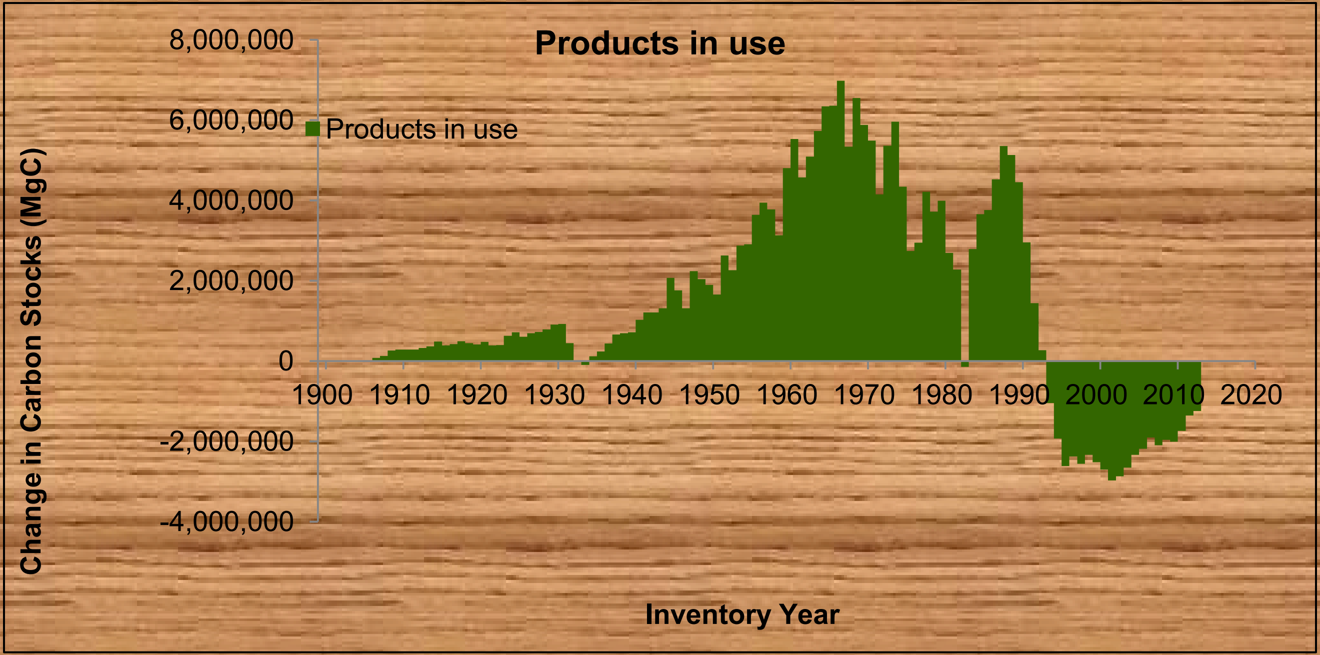
Peaks to Date in Storage and Emissions

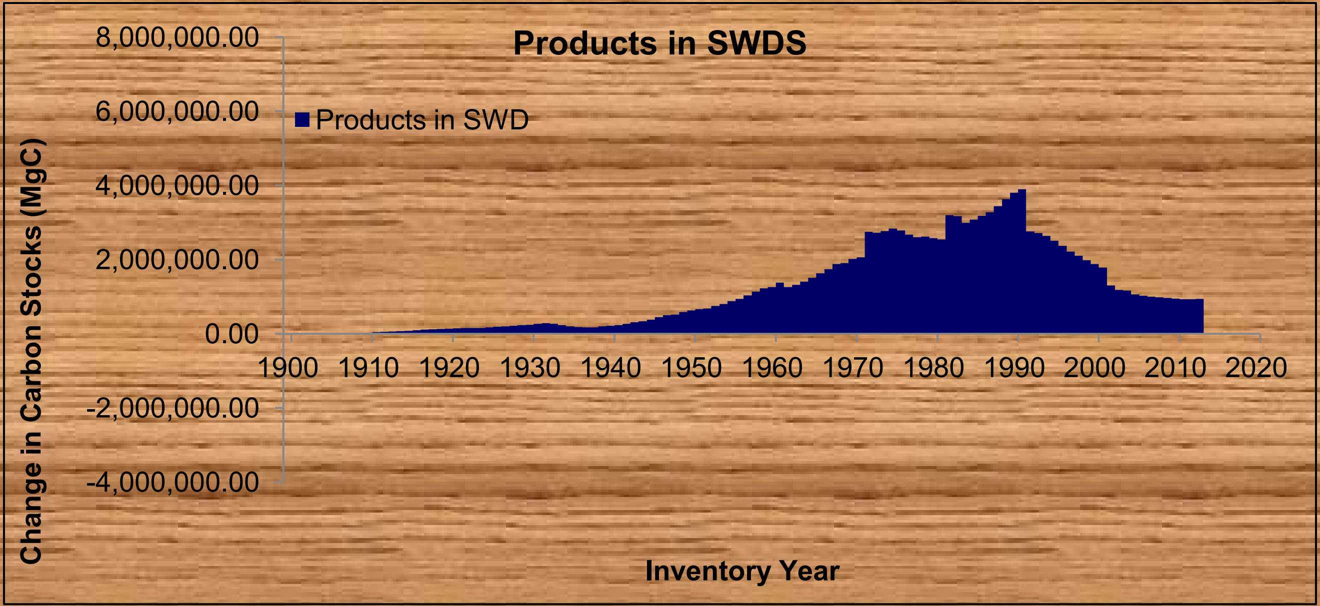
- Peak NFS Products in Use (1993): 203,169,996 MgC
- Peak in NFS Solid Waste Disposal (2013): 132,473,641 MgC
- Peak in NFS Harvested Wood Products (1995): 307,930,946 MgC
- Peak in NFS HWP C storage per US Citizen (1992): 1.16 MgC per Citizen

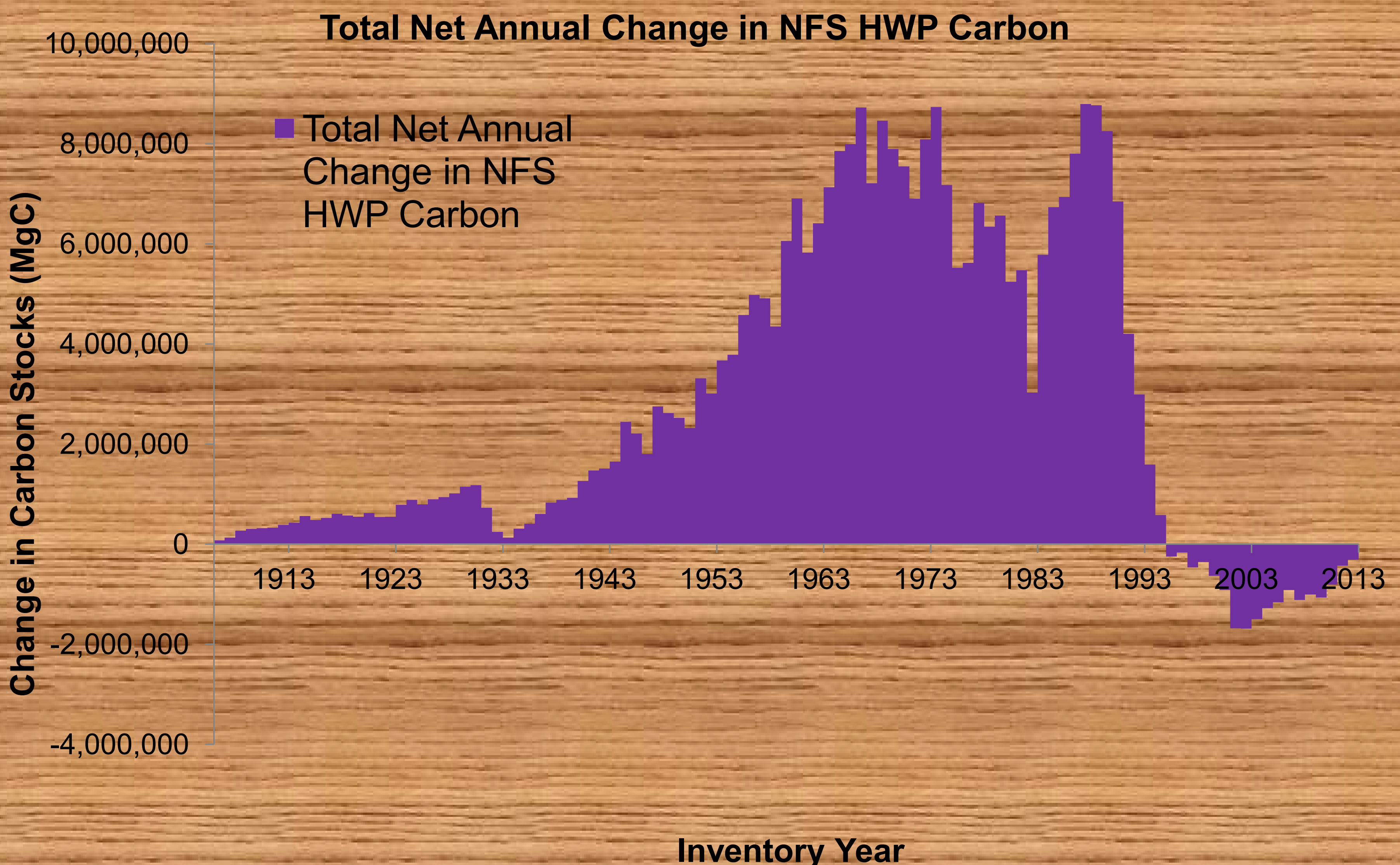
- Peak Positive Annual Change in HWP C Storage(1988): 8.79 TgC
- Peak Negative Annual Change in HWP C Storage(2003):1.69 TgC
- Peak in NFS HWP C emissions per US Citizen per Citizen (2013): 1.45 MgC per Citizen

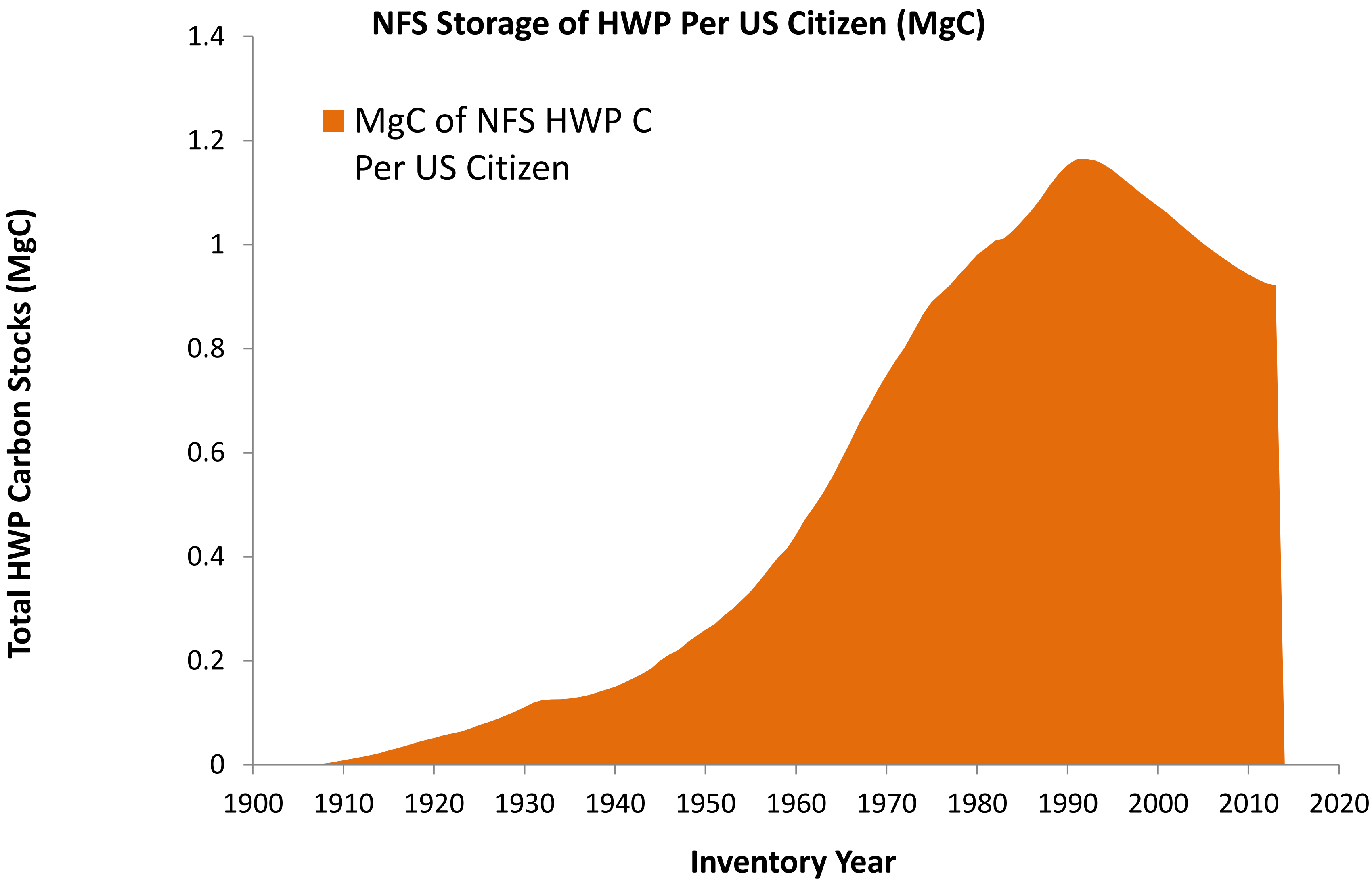
National Emissions




Products in use
Products in use
8,000,000
6,000,000
4,000,000
2,000,000
0
-2,000,000
-4,000,000
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Change in Carbon Stocks (MgC)
Inventory Year


Products in SWDS
Products in SWD
8,000,000.00
6,000,000.00
4,000,000.00
2,000,000.00
0.00
-2,000,000.00
-4,000,000.00
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Change in Carbon Stocks (MgC)
Inventory Year


Total Net Annual Change in NFS HWP Carbon
Total Net Annual Change in NFS HWP Carbon
Change in Carbon Stocks (MgC)
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
-2,000,000
-4,000,000
1913
1923
1933
1943
1953
1963
1973
1983
1993
2003
2013
Inventory Year



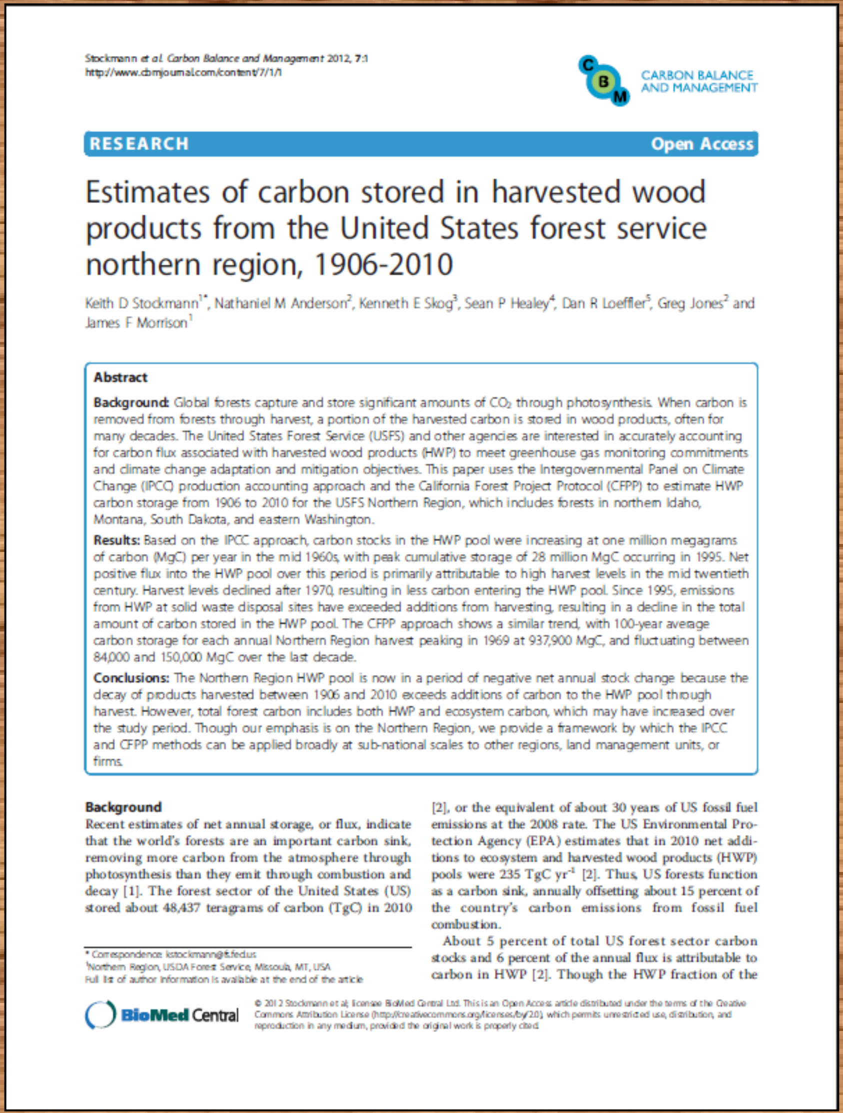
These calculations rely on the increasing US population over time.

Future Work (from 2011 WFE)

- ✓ Complete uncertainty analysis
- ✓ Present results and an early draft of this manuscript to headquarters prior to submission for publication.
- ✓ Submit the manuscript to the international journal, Carbon Balance & Management.
- ✓ Produce estimates for all R1 national forests
- ✓ Develop slideshow of methods and results for FS land managers.
- ✓ Develop web-based results portal for Interdisciplinary teams.
- ✓ General Technical Review with forest level estimates as well as interpretation of the data challenges, the connection between forest and regional estimates.
- ❑ Integrate results with the Forest Carbon Management Framework Decision Support System

Progress

http://www.cbmjournal.com/content/pdf/1750-0680-7-1.pdf



Stockmann *et al. Carbon Balance and Management* 2012, 7:1
http://www.cbmjournal.com/content/7/1/1

CARBON BALANCE AND MANAGEMENT

RESEARCH — Open Access

Estimates of carbon stored in harvested wood products from the United States forest service northern region, 1906-2010

Keith D Stockmann[1*], Nathaniel M Anderson[2], Kenneth E Skog[3], Sean P Healey[4], Dan R Loeffler[5], Greg Jones[2] and James F Morrison[1]

Abstract

Background: Global forests capture and store significant amounts of CO_2 through photosynthesis. When carbon is removed from forests through harvest, a portion of the harvested carbon is stored in wood products, often for many decades. The United States Forest Service (USFS) and other agencies are interested in accurately accounting for carbon flux associated with harvested wood products (HWP) to meet greenhouse gas monitoring commitments and climate change adaptation and mitigation objectives. This paper uses the Intergovernmental Panel on Climate Change (IPCC) production accounting approach and the California Forest Project Protocol (CFPP) to estimate HWP carbon storage from 1906 to 2010 for the USFS Northern Region, which includes forests in northern Idaho, Montana, South Dakota, and eastern Washington.

Results: Based on the IPCC approach, carbon stocks in the HWP pool were increasing at one million megagrams of carbon (MgC) per year in the mid 1960s, with peak cumulative storage of 28 million MgC occurring in 1995. Net positive flux into the HWP pool over this period is primarily attributable to high harvest levels in the mid twentieth century. Harvest levels declined after 1970, resulting in less carbon entering the HWP pool. Since 1995, emissions from HWP at solid waste disposal sites have exceeded additions from harvesting, resulting in a decline in the total amount of carbon stored in the HWP pool. The CFPP approach shows a similar trend, with 100-year average carbon storage for each annual Northern Region harvest peaking in 1969 at 937,900 MgC, and fluctuating between 84,000 and 150,000 MgC over the last decade.

Conclusions: The Northern Region HWP pool is now in a period of negative net annual stock change because the decay of products harvested between 1906 and 2010 exceeds additions of carbon to the HWP pool through harvest. However, total forest carbon includes both HWP and ecosystem carbon, which may have increased over the study period. Though our emphasis is on the Northern Region, we provide a framework by which the IPCC and CFPP methods can be applied broadly at sub-national scales to other regions, land management units, or firms.

Background

Recent estimates of net annual storage, or flux, indicate that the world's forests are an important carbon sink, removing more carbon from the atmosphere through photosynthesis than they emit through combustion and decay [1]. The forest sector of the United States (US) stored about 48,437 teragrams of carbon (TgC) in 2010 [2], or the equivalent of about 30 years of US fossil fuel emissions at the 2008 rate. The US Environmental Protection Agency (EPA) estimates that in 2010 net additions to ecosystem and harvested wood products (HWP) pools were 235 TgC yr^{-1} [2]. Thus, US forests function as a carbon sink, annually offsetting about 15 percent of the country's carbon emissions from fossil fuel combustion.

About 5 percent of total US forest sector carbon stocks and 6 percent of the annual flux is attributable to carbon in HWP [2]. Though the HWP fraction of the

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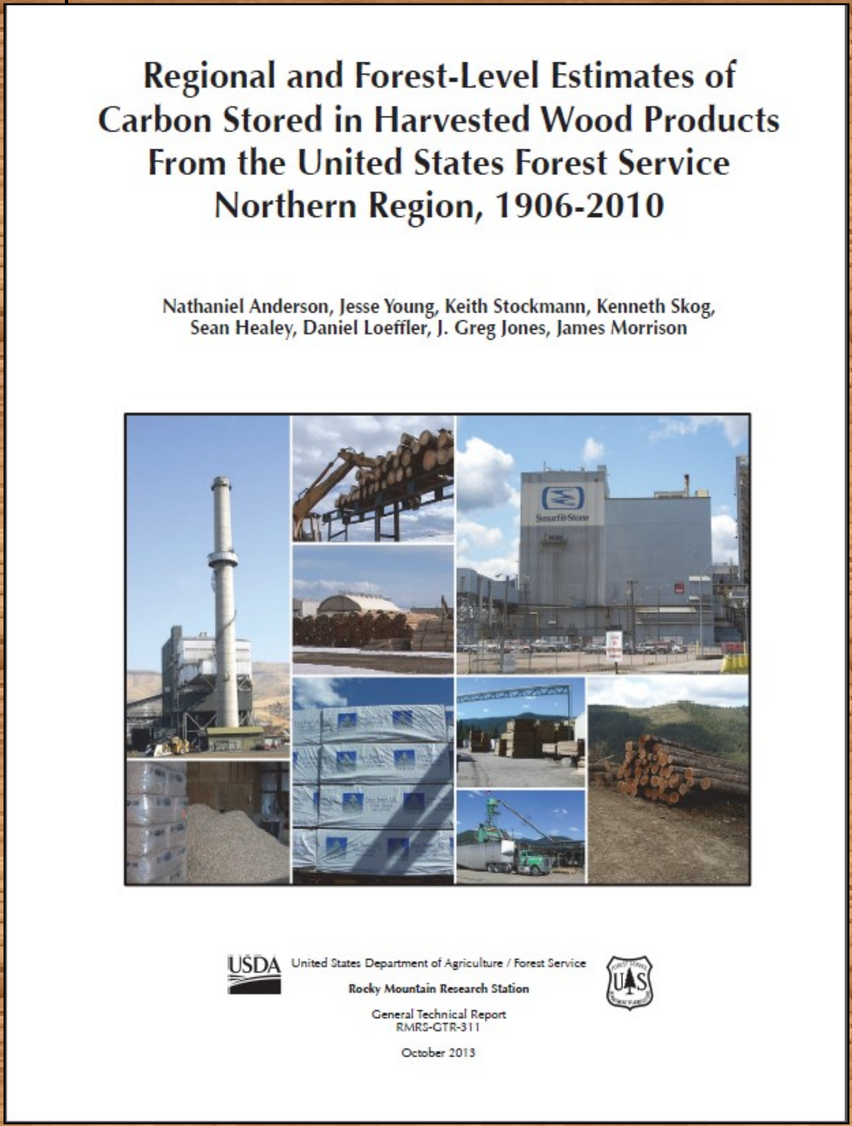
BioMed Central

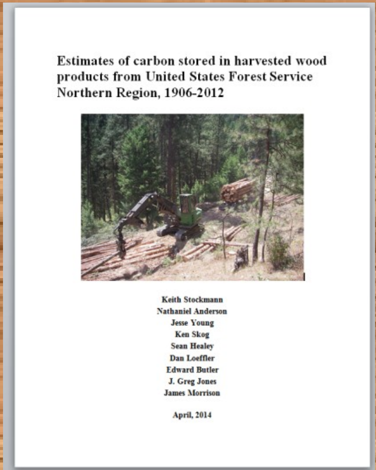
http://www.fs.fed.us/rm/pubs/rmrs_gtr311.pdf



Regional and Forest-Level Estimates of Carbon Stored in Harvested Wood Products From the United States Forest Service Northern Region, 1906-2010

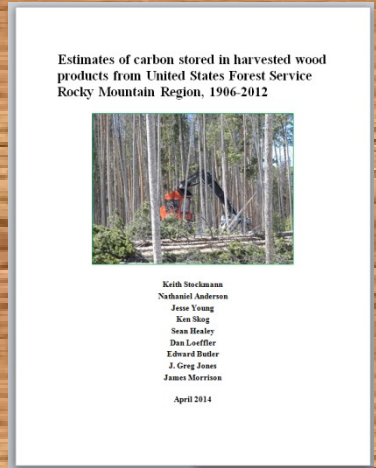
Nathaniel Anderson, Jesse Young, Keith Stockmann, Kenneth Skog, Sean Healey, Daniel Loeffler, J. Greg Jones, James Morrison

USDA United States Department of Agriculture / Forest Service
Rocky Mountain Research Station
General Technical Report
RMRS-GTR-311
October 2013


Estimates of carbon stored in harvested wood products from United States Forest Service Northern Region, 1906-2012

Keith Stockmann
Nathaniel Anderson
Jesse Young
Ken Skog
Sean Healey
Dan Loeffler
Edward Butler
J. Greg Jones
James Morrison

April, 2014


Estimates of carbon stored in harvested wood products from United States Forest Service Rocky Mountain Region, 1906-2012

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Nathaniel Anderson
Jesse Young
Ken Skog
Sean Healey
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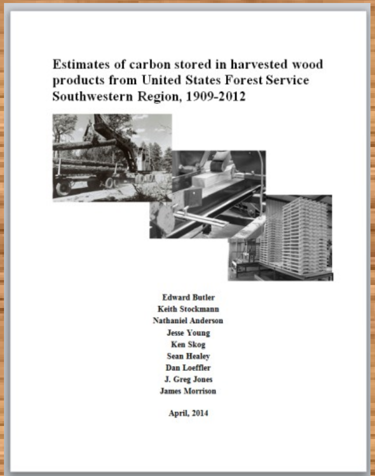
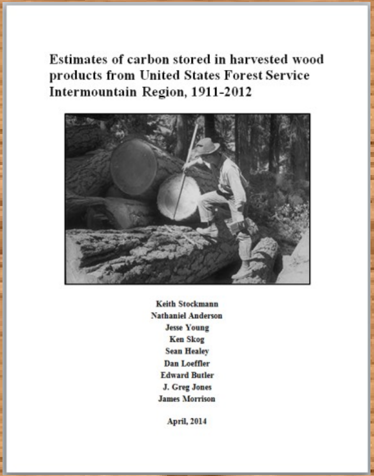
J. Greg Jones
James Morrison

April 2014


Estimates of carbon stored in harvested wood products from United States Forest Service Southwestern Region, 1909-2012

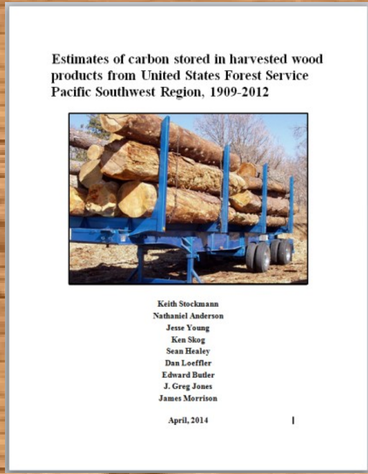
Edward Butler
Keith Stockmann
Nathaniel Anderson
Jesse Young
Ken Skog
Sean Healey
Dan Loeffler
J. Greg Jones
James Morrison

April, 2014


Estimates of carbon stored in harvested wood products from United States Forest Service Intermountain Region, 1911-2012

Keith Stockmann
Nathaniel Anderson
Jesse Young
Ken Skog
Sean Healey
Dan Loeffler
Edward Butler
J. Greg Jones
James Morrison

April, 2014


Estimates of carbon stored in harvested wood products from United States Forest Service Pacific Southwest Region, 1909-2012

Keith Stockmann
Nathaniel Anderson
Jesse Young
Ken Skog
Sean Healey
Dan Loeffler
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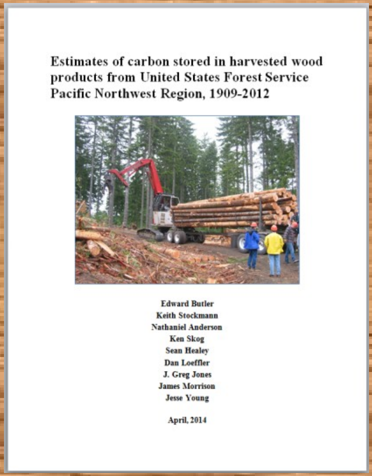
April, 2014


Estimates of carbon stored in harvested wood products from United States Forest Service Pacific Northwest Region, 1909-2012

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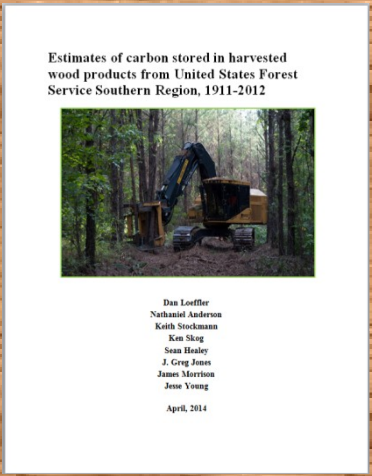
Estimates of carbon stored in harvested wood products from United States Forest Service Southern Region, 1911-2012

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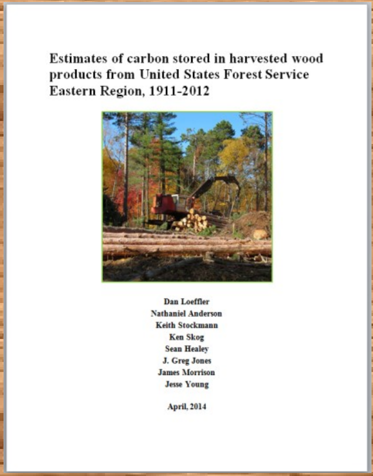
Estimates of carbon stored in harvested wood products from United States Forest Service Eastern Region, 1911-2012

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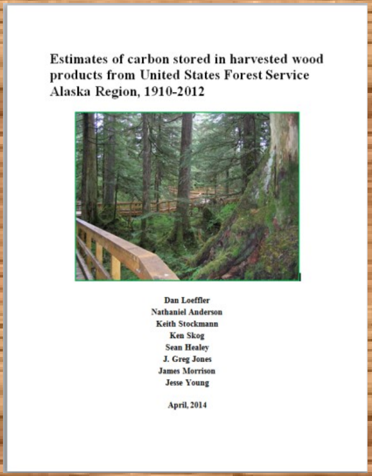
Estimates of carbon stored in harvested wood products from United States Forest Service Alaska Region, 1910-2012

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Next Steps

- ForCaMF
- White Paper
- General Technical Review
- Forest-level reporting at the Forest Management Service Center?
- Comparative Analyses:
  - In context of Ecosystem Carbon
  - Between regions
  - Between tree types > products> end uses
- Market Participation?

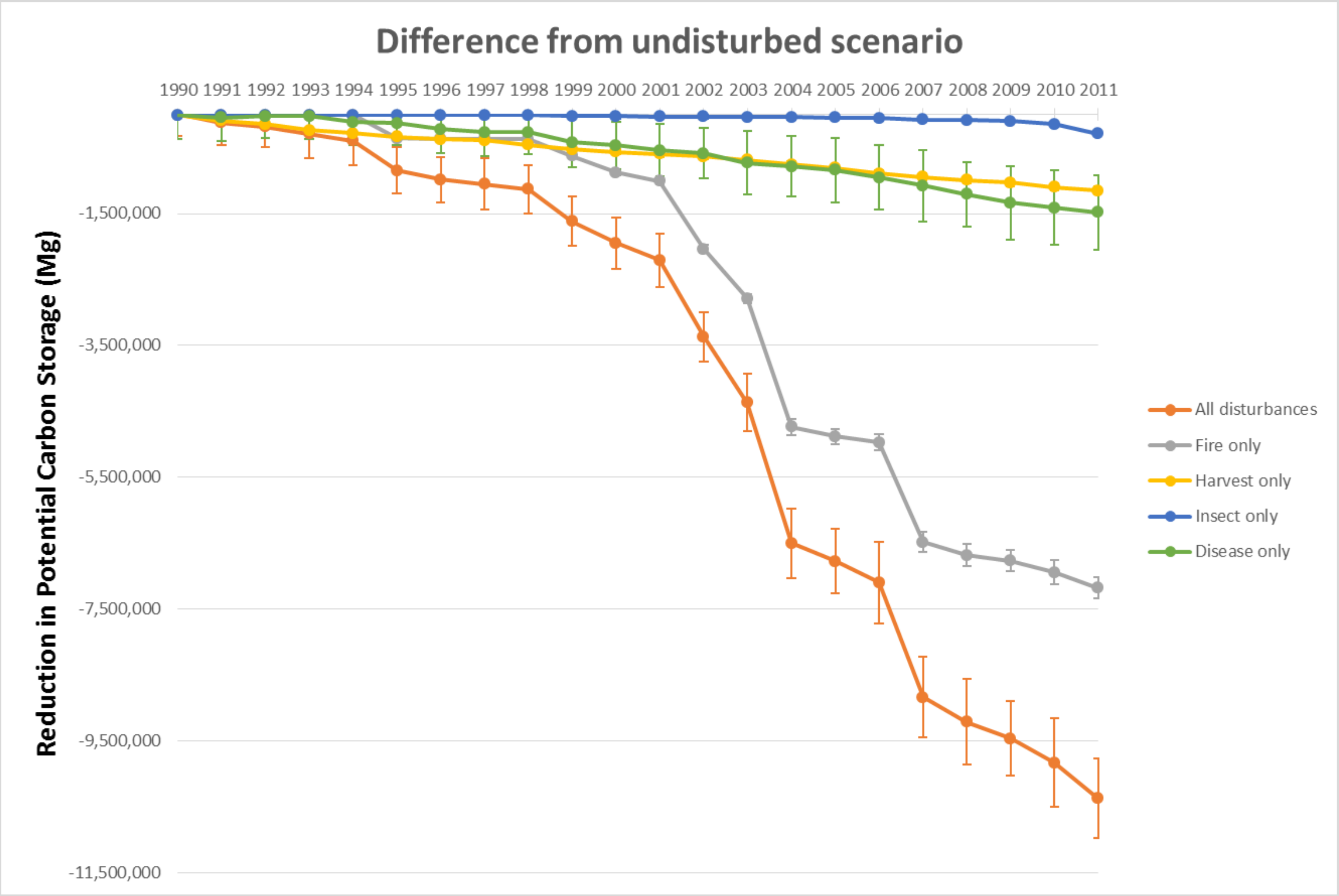
Thinking about emissions versus storage, and storage in different pools

- Consider Jamie Barber’s work suggesting thinning may store more carbon by reducing wildfire emissions
- Emphasis of ForCaMF and future work

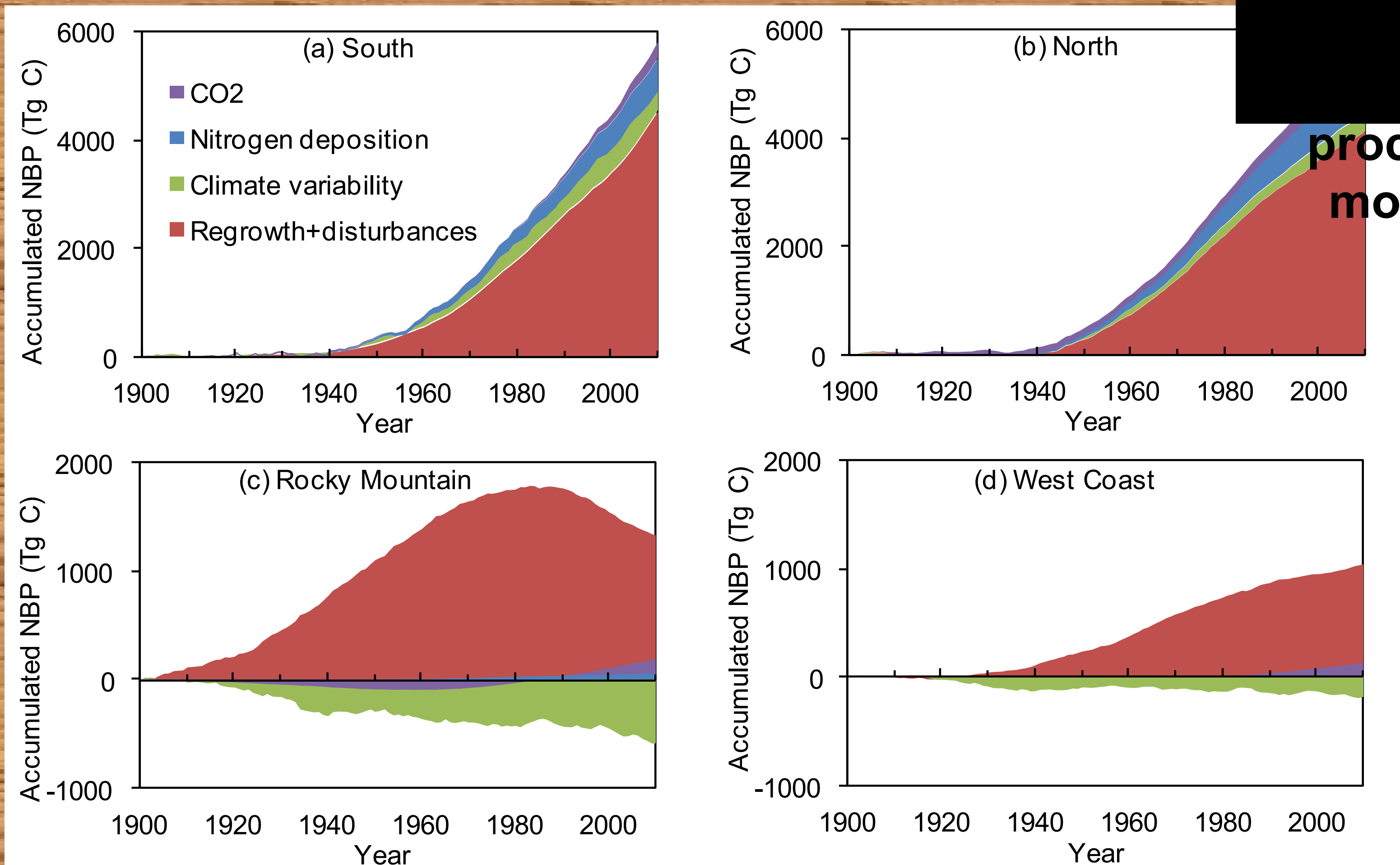
Forest Carbon Management Framework (ForCaMF)

- Forest Carbon Management Framework has been developed through a partnership between the Forest Service and NASA.
- Landsat imagery and inventory data are critical to how ForCaMF visualizes the distribution of both forest carbon stocks and stock-resetting disturbances (e.g., harvests and fires) across planning units. Imagery is also used to measure relevant fossil carbon emissions by quantifying forest road construction activity and pinpointing how far harvested timber must be hauled to processing facilities.
- The carbon dynamics built into ForCaMF are derived from the Forest Vegetation Simulator (FVS).
- ForCaMF integrates monitoring of both ecological and non-ecological forest carbon dynamics under a probabilistic estimation framework, allowing annual assessment of carbon stocks and fluxes as they respond to particular harvest strategies and natural disturbance trends.
- ForCaMF has been piloted in Ravalli Co. Montana and is currently being installed across all Forest Service land in the Northern Rockies.
- As a decision support system, ForCaMF is providing insight into the relationship between forest management and carbon storage at the local and regional scales where most forest management actually occurs.

Phase 1.B – Example: Flathead NF



Phase 1.B – Example: Effects of Main Factors on Accumulated NBP (kg C m^{-2}, 1901-201[redacted]



[redacted]
process model

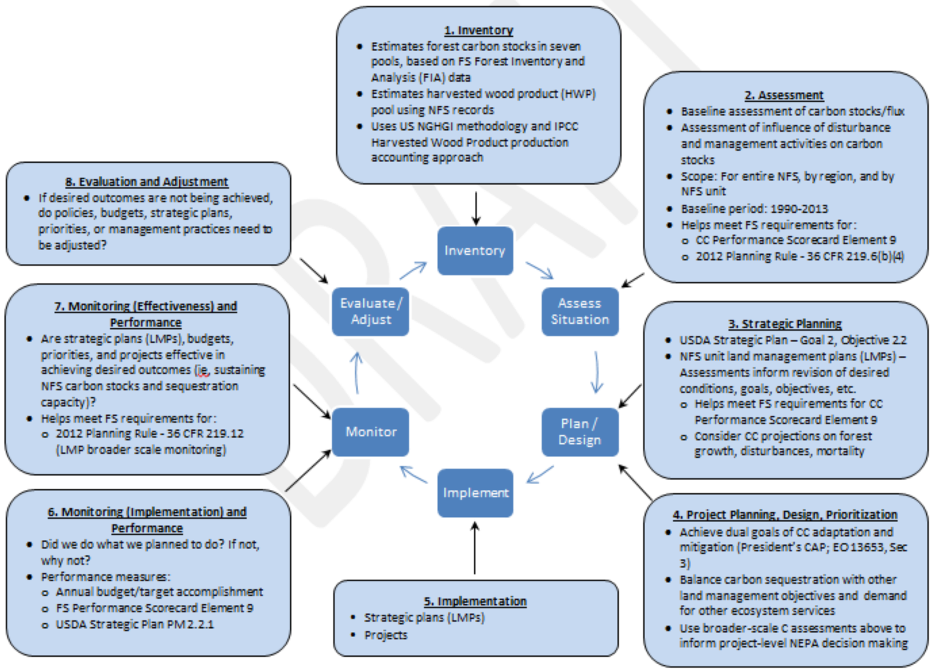
Framework for Sustainable Management of Forest Ecosystem Carbon

Forest Service Approach for National Forest System Lands

Overall goal: Sustain or increase carbon sequestration capacity of National Forest System lands while:

a. Restoring and maintaining resilient forests to be better adapted to a changing climate and other stressors, and
b. Delivering on other land management objectives and ecosystem services in accordance with the FS mission and authorities.

Principle-based carbon management: FS sustains forest ecosystem carbon through application of six forest carbon principles (see next page).



Forest Carbon Principles (short version)

Forest carbon management (carbon stewardship) may best be articulated through the following principles and guidelines. They are intended to provide considerations for integrating carbon management with planning and implementation processes and with efforts to adapt forests to the impacts of a changing climate.

1. **Emphasize ecosystem function and resilience. (Function First).** Carbon sequestration capacity depends on sustaining and enhancing ecosystem function to maintain resilient forests adapted to changing climate and other conditions.

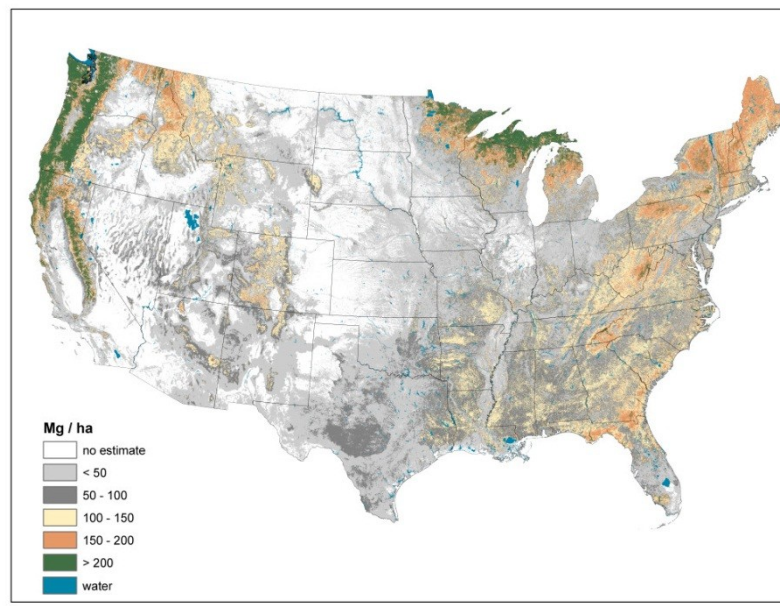
2. **Recognize carbon sequestration as one of many ecosystem services. (One of Many Services).** Carbon sequestration is one of many benefits provided by forests, grasslands, and forest products, now and in the future. Carbon sequestration should be considered in context with other ecosystem services.

3. **Support diversity of approach in carbon exchange and markets. (Diverse Markets).** Recognize that decisions about carbon in America's forests are influenced by ownership goals, policy, ecology, geography, socioeconomic concerns, and other factors that vary widely.

4. **Consider system dynamics and scale in decision making. (Scale and Timeframe).** Evaluate carbon sequestration and cycling at landscape scales over long time frames. Explicitly consider uncertainties and assumptions in evaluating carbon sequestration consequences of forest and grassland management options.

5. **Use the best information and methods to make decisions about carbon management. (Decision Quality).** Base forest management and policy decisions on the best available science-based knowledge and information about system response and carbon cycling in forests, grasslands, and wood products. Use this information wisely by dealing directly with uncertainties, risks, opportunities, and tradeoffs through sound and transparent risk management practices.

6. **Strive for program integration and balance. (Program Alignment)** Carbon management is part of a balanced and comprehensive program of sustainable forest management and climate change response. As such, forest carbon strategies have ecological, economic, and social implications and interactions with other Forest Service programs and strategies, such as those for energy and water.



Outline for General Technical Review Explaining the USFS Approach to Carbon Modeling and Management

USFS National Forest System Carbon Assessment Strategy: A General Technical Report

Summary: This technical report describes the U.S. Forest Service approach to conducting assessments of carbon stocks, trends, and causes of change on National Forests. Documentation of the NFS carbon assessment strategy is dispersed and appears mostly in specialized journals. There is a need to provide the land managers and policy analysts a coherent description of how the different pieces work together to meet the specific planning needs that have been spelled out in various mandates. This description provides an accessible yet clear overview of the inventory, monitoring, and analysis techniques used to provide NFS with credible and nationally consistent carbon information at the scale of individual National Forests, or aggregated to regions and the nation. The document provides a link to the best available science that underlays development of carbon assessments for the National Forests. This is the technical complement to the "how to implement carbon in forest planning" document that Greg Kujawa, Jim Alegria, and others are working on. Target length is approximately 100 pages of text, tables, graphics, and references, all presented clearly using plain language but containing sufficient technical detail to describe the methodologies and underlying science. .

The document will include supplemental on-line material, links to "O" drive documents and data sets including the meta-data necessary for guiding appropriate use of the referenced data. This supplemental material will include, where appropriate, a Digital Object Identifier (DOI).

1. Context
    a. Importance of land management in mitigating climate change (*Cleaves*)
    b. NFS mandates for carbon accounting (*Kujawa*)
        i. Scorecard
        ii. Planning Rule
        iii. Executive Order(s)
    c. Assessment needs
        i. Clearly Identified Assessment Properties and Assumptions (*Skog*)
        ii. Carbon stocks and stock changes (*Birdsey*)
            1. Ecosystem pools
            2. Product pools
        iii. Assessing occurrence and severity of drivers of change: management and natural disturbance (*Healey*)
        iv. Linkage with systematic monitoring data such as FIA and NFS vegetation information (*Healey* - building on existing data)
            1. Designed sample forms the basis for uncertainty estimation
            2. Provides consistency with data supporting other Plan elements
        v. Spatial scale, maps, and data limitations (*Alexa* and others)
2. Carbon stock and stock change estimation NOTE: in this and the next section, each of the assessment components should address system boundaries, integration with other parts, approach to estimating uncertainty, and links to institutional resources such as FVS, FSVEG, FIA, disturbance mapping, etc.
    a. CCT/FIA (*Woodall*)
    b. Product carbon accounting (*Stockman, Skog, Hoover*)
3. Effects of natural disturbance, climate and management on carbon
    a. Literature review of disturbance and climate effects on carbon storage (*Birdsey*)
    b. Literature review of management effects on carbon storage (*McCarter*)
    c. Difference between process models and growth/yield models (*Birdsey*)
        i. Two approaches have different relative strengths
            1. Growth/Yield models have high empirical calibration and are consistent with other planning tools used by NFS
            2. Process models allow consideration of climate and air pollution effects on growth and decay rates, and with empirical calibration can be made consistent with inventory-based approaches
            3. Both allow consideration of changing disturbance rates, which may be the most significant impact of changing climate on carbon storage
    d. ForCaMF (*Healey*)
    e. InTEC (*Zhang et al.*)
4. Expected baseline analyses for every Forest/Region (*Dante and Dowd* to provide guidance)
    a. Use Region 1 as an example? Use the most local analysis that is available (region or forest), show at least one forest as an example. Maybe an example or two comparing multiple forests or all forests in a region. Bottom up approach – scale up toregion.
    b. How to use this system – general guidance
5. Future directions (*Healey and Birdsey and Woodall*)
    a. Improvements in FIA accounting and CCT
    b. Going from Regional to Forest-level product carbon accounting
    c. Going beyond National Forest boundaries
    d. Capacity of ForCaMF and InTEC to address scenarios of interest – include strengths and limitations for supporting planning, e.g., does this system deal with thinning, restoration, etc. How to link this with management prescriptions. (maybe not sufficient to include this).
    e. Include LCA
    f. How to integrate with forest plans, making projections, etc.
6. Appendix A – Nationally consistent data sets and maps produced and archived for NFS through carbon monitoring activities (*McCullough, Dugan, others*)
    a. Disturbance products (type, location, severity, date)
    b. Biomass maps
    c. Productivity? Others?
    d. Climate and air pollution
    e. Forest age map
    f. NDVI
    g. Soils

Questions, Comments or Suggestions?

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