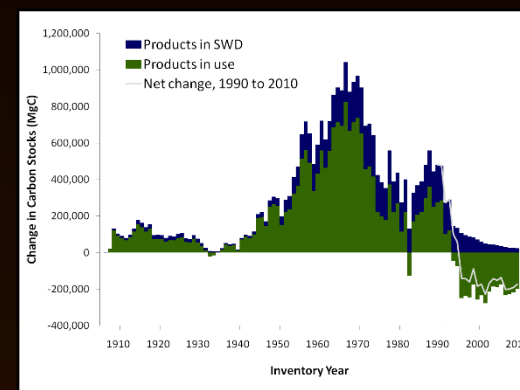
An Overview of IPCC HWP Carbon Accounting Methods with a Focus on the Production Accounting Approach



Nate Anderson, Research Forester
Rocky Mountain Research Station

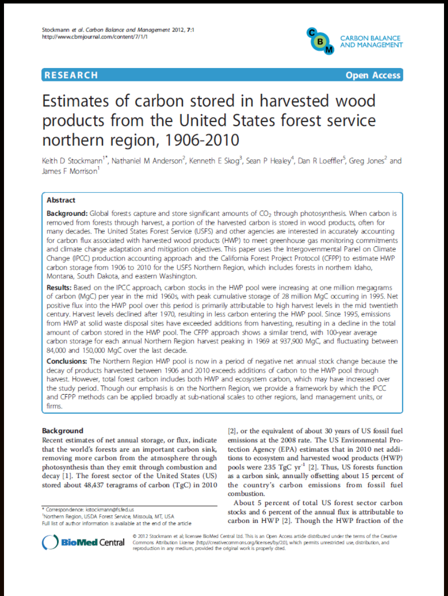
ODF Forest Carbon Accounting Stakeholder Meeting
October 18, 2018

Ahead

- Background
- Methods
  - IPCC methods overview
  - Production accounting approach
- Example: USFS Northern Region
  - Results
  - Interpretation and implications
- Questions and Discussion

Team Effort

- Region 1 Project Team (2010-2012)
  - Keith Stockmann, USFS Region 1
  - Nate Anderson, USFS RMRS
  - Ken Skog, USFS Forest Products Lab
  - Sean Healey, USFS RMRS-FIA
  - Dan Loeffler, U. of Montana
  - J. Greg Jones, USFS RMRS
  - Jim Morrison, USFS Region 1
  - Jesse Young, U. of Montana
- Funding: USFS Region 1



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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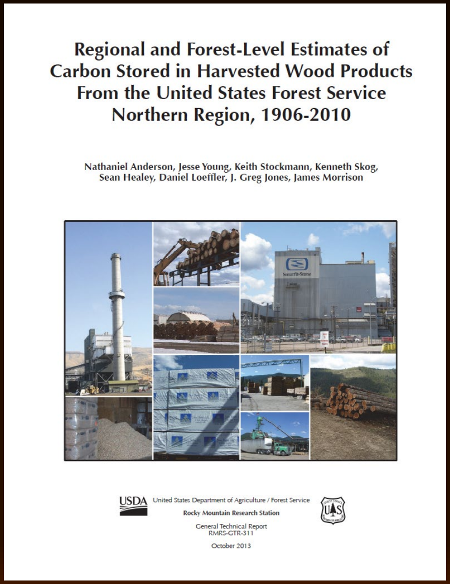


Regional and Forest-Level Estimates of Carbon Stored in Harvested Wood Products From the United States Forest Service Northern Region, 1906-2010

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

United States Department of Agriculture / Forest Service

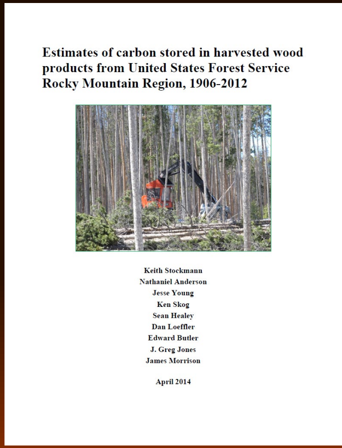
Rocky Mountain Research Station

General Technical Report
RMRS-GTR-311

October 2013

Team Effort

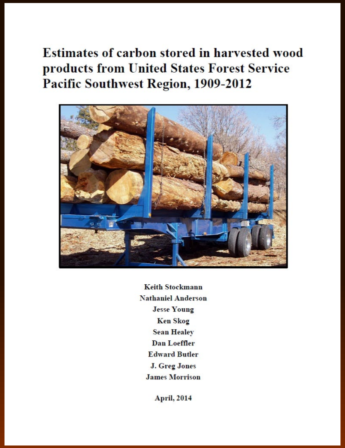
- NFS HWP Accounting Project Team (2012-2014)
  - Keith Stockmann, USFS Region 1 (now at TDC)
  - Dan Loeffler, University of Montana
  - Jesse Young, University of Montana
  - Ed Butler, University of Montana
- Funding: U.S. Forest Service



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

Keith Stockmann
Nathaniel Anderson
Jesse Young
Ken Skog
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Dan Loeffler
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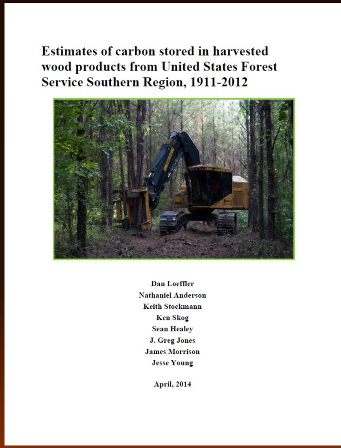
James Morrison

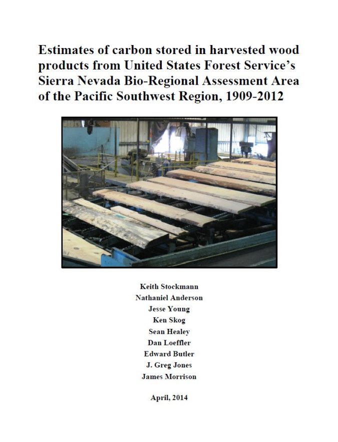
April, 2014



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

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

April, 2014



Estimates of carbon stored in harvested wood products from United States Forest Service's Sierra Nevada Bio-Regional Assessment Area of the Pacific Southwest Region, 1909-2012

Keith Stockmann
Nathaniel Anderson
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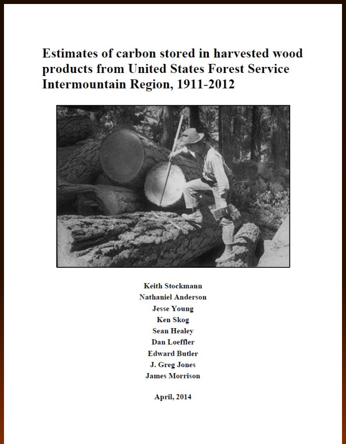
James Morrison

April, 2014



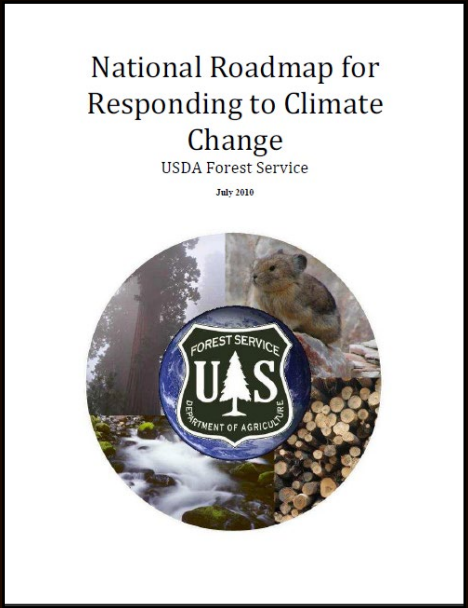
Estimates of carbon stored in harvested wood products from United States Forest Service Intermountain Region, 1911-2012

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

April, 2014

Background: Why?

- Ecosystem Service: Carbon Sink
- USFS Forest Carbon Management
  - Climate Change Mitigation and Adaptation Strategy
  - Climate Change Roadmap
  - Climate Change Scorecard
- Need measurement & monitoring
- Need for jurisdictional and firm-level accounting
  - Apply National/EPA protocols to smaller units
  - Apply state & regional protocols (e.g. CA-FPP)



Background: Why?

- USFS Climate Change Scorecard

The Forest Service Climate Change Performance Scorecard

Each national forest and grassland is expected to do seven of the following by 2015:

1. Provide all employees with education on climate change
2. Assign at least one employee as a point person for climate change issues
3. Incorporate climate change into guidance, training, and plans of work
4. Integrate science and forest management practices through new and existing partnerships
5. Incorporate climate change into new and existing external partnerships
6. Assess the vulnerability of ecosystems and human communities to climate change
7. Develop climate change adaptation strategies for vulnerable resources
8. Monitor climate change impacts and the effectiveness of climate change strategies
9. Assess carbon stocks and flows and develop carbon management strategies
10. Set targets to reduce the environmental footprint from their operations

For a more detailed version of the scorecard, please go to:
http://www.fs.fed.us/climatechange/pdf/performance_scorecard_final.pdf

USDA Forest Service
Office of the Chief
Climate Change Advisor
September 2010

Background: Objectives

For the U.S. Forest Service:

- OPERATIONALIZE HWP accounting methods
- Estimate annual stock change from our lands
- Provide decision support

For others:

- Provide a Regional example of HWP accounting
- Develop a system to apply elsewhere

Background: Global Carbon

- Partitioning emissions

$$E_{FF} + E_{LUC} = G_{ATM} + S_{OCEAN} + S_{LAND}$$

- E_{FF} = Emissions, fossil fuel and cement
- E_{LUC} = Emissions, land use change
- G_{ATM} = Growth of CO_2 in the atmosphere
- S_{OCEAN} = Uptake (sink) by the ocean
- S_{LAND} = Uptake (sink) by the land

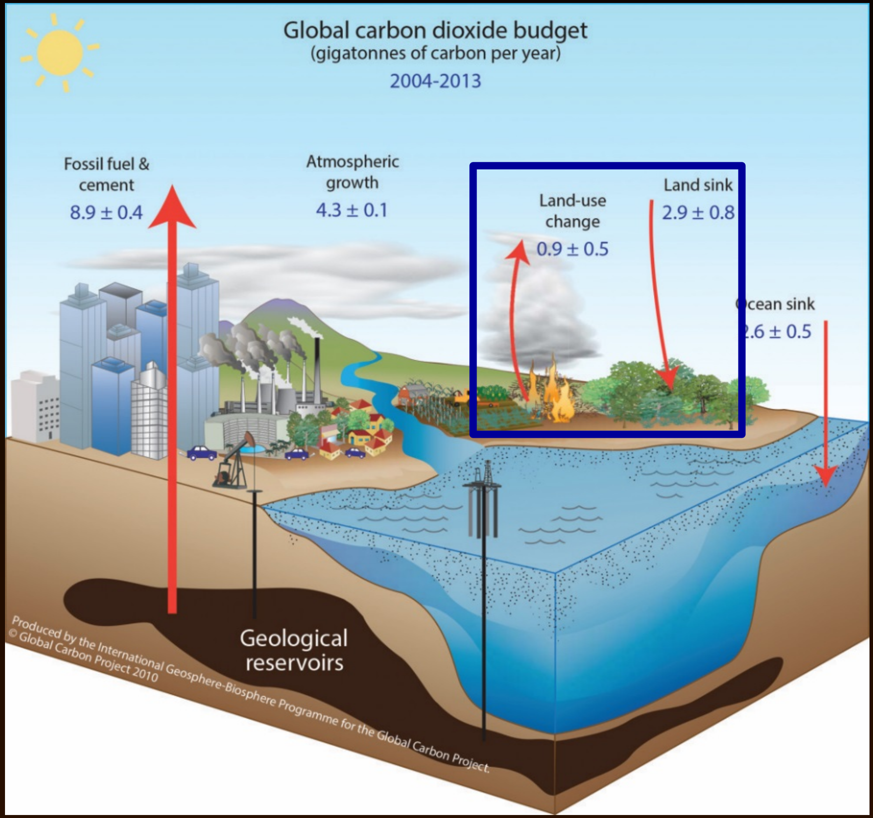


Figure from Le Quere et al. 2015

Background: Global Carbon

- Partitioning emissions
- Reporting Sectors
  - Energy
  - Industrial Processes
  - Waste
  - Solvents/Product Use
  - Agriculture, Forestry & Other Land Use (AFOLU)

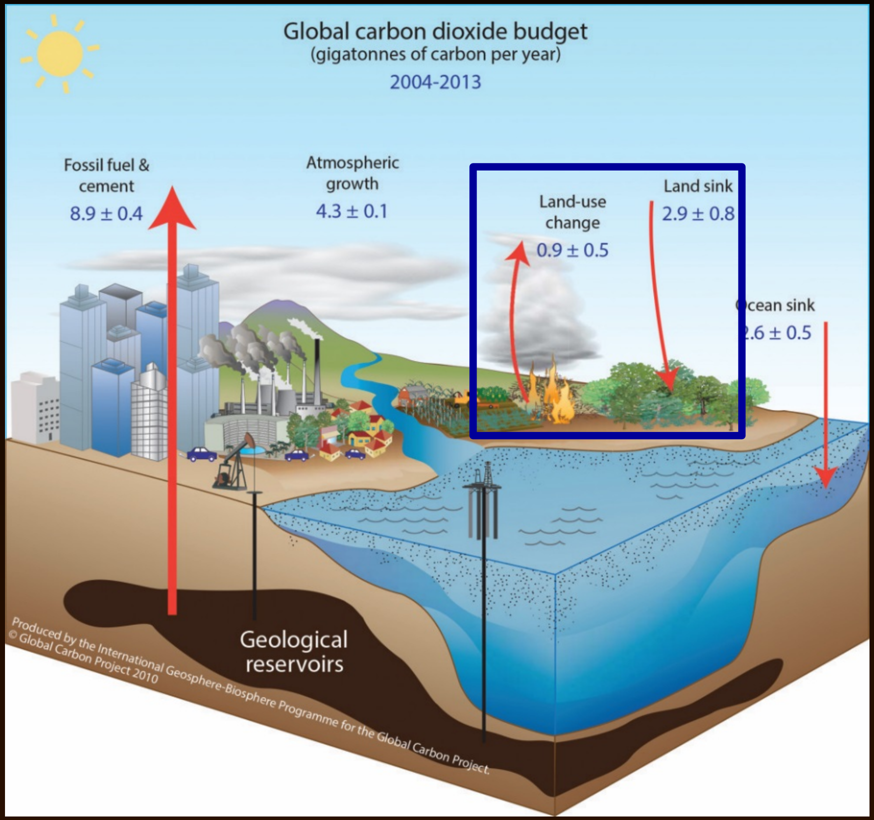
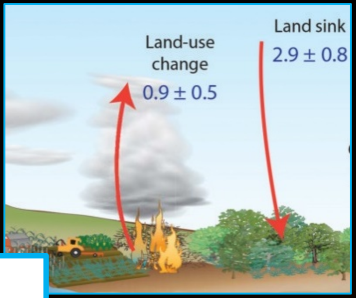


Figure from Le Quere et al. 2015

Background: Global Carbon



E_{LUC} & S_{LAND} (GtC)

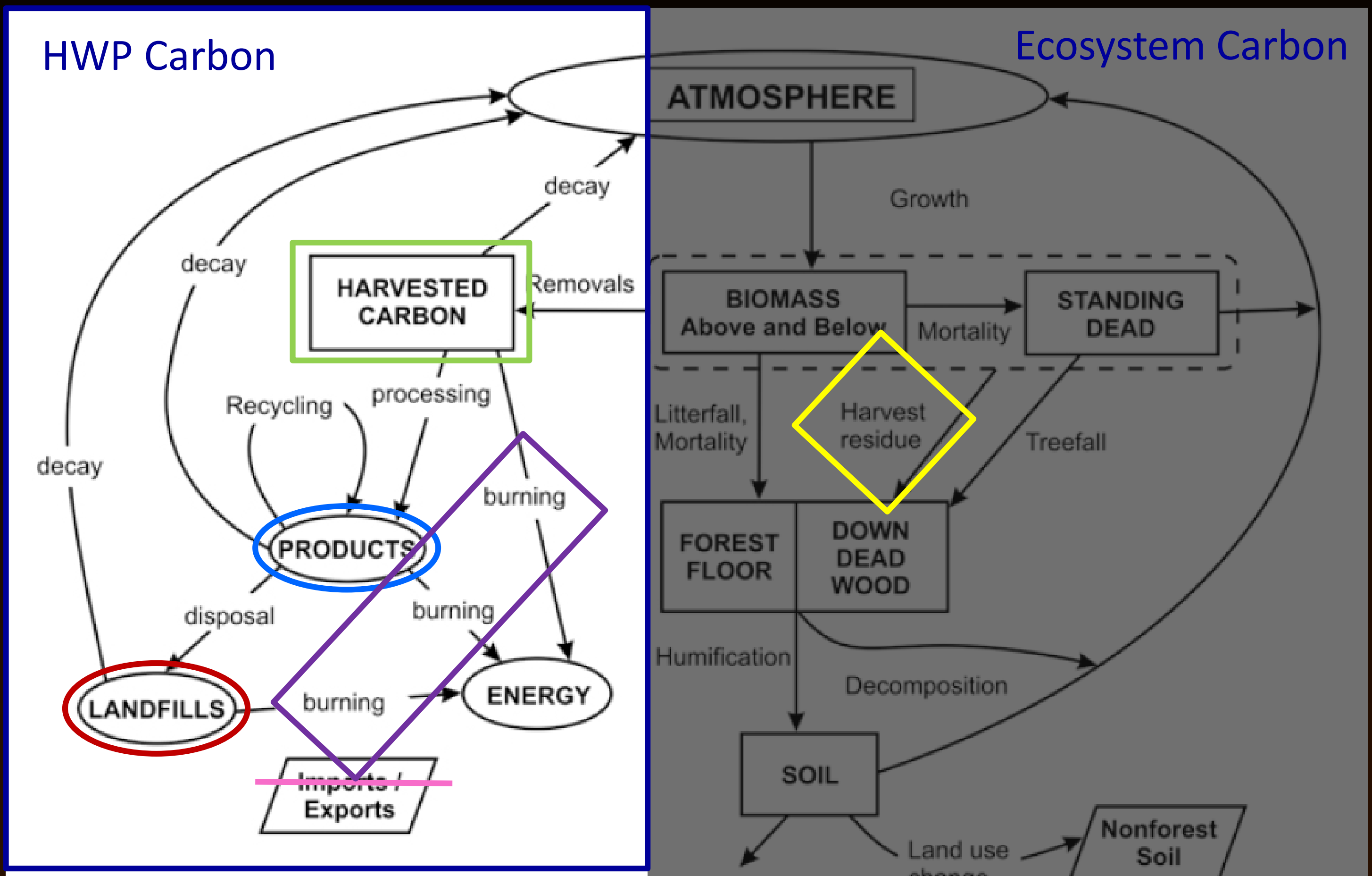
- Forest Carbon Flux

Table from Pan et al. 2011

Table 1. Global forest carbon budget (Pg C $year^{-1}$) over two time periods. Sinks are positive values; sources are negative values.

Carbon sink and source in biomes	1990–1999	2000–2007	1990–2007
Boreal forest	0.50 ± 0.08	0.50 ± 0.08	0.50 ± 0.08
Temperate forest	0.67 ± 0.08	0.78 ± 0.09	0.72 ± 0.08
Tropical intact forest*	1.33 ± 0.35	1.02 ± 0.47	1.19 ± 0.41
Total sink in global established forests†	2.50 ± 0.36	2.30 ± 0.49	2.41 ± 0.42
Tropical regrowth forest‡	1.57 ± 0.50	1.72 ± 0.54	1.64 ± 0.52
Tropical gross deforestation emission§	–3.03 ± 0.49	–2.82 ± 0.45	–2.94 ± 0.47
Tropical land-use change emission‖	–1.46 ± 0.70	–1.10 ± 0.70	–1.30 ± 0.70
Global gross forest sink¶	4.07 ± 0.62	4.02 ± 0.73	4.05 ± 0.67
Global net forest sink#	1.04 ± 0.79	1.20 ± 0.85	1.11 ± 0.82

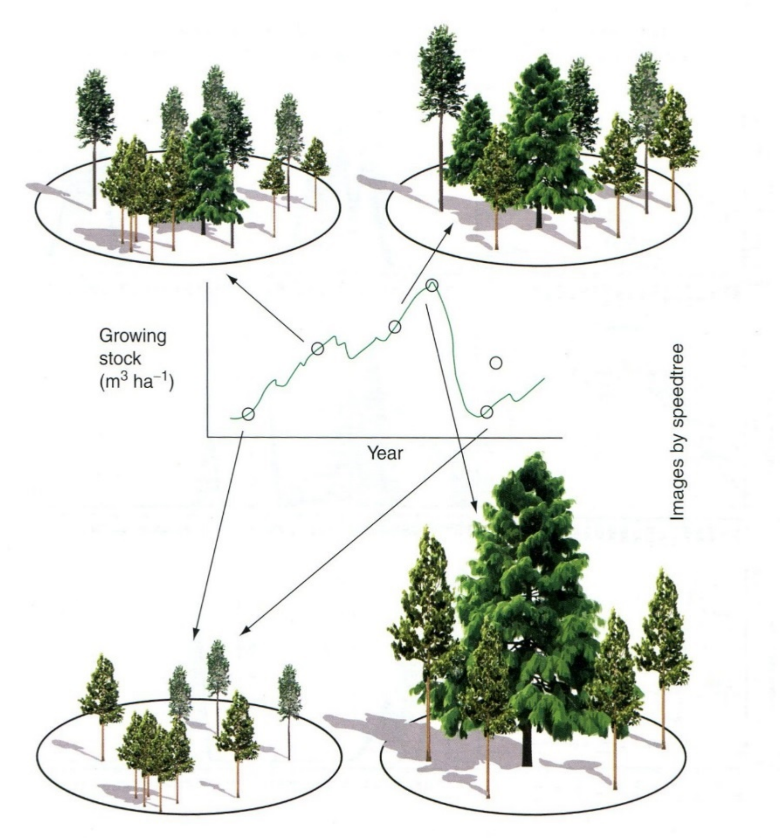
Background: Forest Carbon



Heath et al. 2009

Background: Who cares?

- HWP pool is much smaller than ecosystem pool
  - US: 5% stocks, 11% flux
- Role of Management
  - Reduce deforestation
  - Increase silviculture
  - Protect soil
  - Retain carbon
  - Increase growth
  - Increase stocks in both:
    - Ecosystem
    - HWP



Coomes et al. 2014

A Good Accounting System

Transparent, consistent, comparable, complete, accurate, verifiable, and efficient recording and reporting of changes in carbon stocks and/or changes in emissions by sources and removals by sinks from applicable land use, land-use change, and forestry activities and projects.

IPCC report on Land Use, Land-Use Change and Forestry (LULUCF)

Common Accounting Approaches

- National GHG Inventory
  - e.g. IPCC guidelines
- Life Cycle Assessment
  - Quantify and compare environmental impacts of products
  - GHG, energy, efficiency ($), toxics, etc.
- Project-based accounting
  - California Forest Project Protocol
  - REDD+

Common Accounting Approaches

GHG Inventory

Life Cycle Assessment (LCA)

Project-based accounting

How does wood compare to steel?

How many carbon credits from longer rotations?

What is the stock change (flux) across all of our lands?

What's up with forest bioenergy anyway?

Common Accounting Approaches

GHG Inventory

- Energy
- Industrial Processes
- Waste/Product Use
- AFOLU

Life Cycle Assessment (LCA)

Project-based accounting

Diesel fuel from log trucks

Fossil fuel "offsets" from bioenergy

Gains or losses from substituting wood for aluminum

Methane from decomposition in landfills

Carbon in soils and roots

"Leakage" from lower harvest

Methods: IPCC HWP Inventory

<u>What are my options?</u>

1. Ignore HWP (IPCC Tier 1 Default)
   - Remove Harvest from the Ecosystem pool
   - All HWP carbon is oxidized in the year of harvest
   - Zero net flux in the HWP pool

2. HWP Carbon Accounting
   - Choose a tier
   - Choose an approach

Methods: IPCC HWP

What are my options?

1. Ignore HWP (IPCC Tier 1 Default)
   - Remove Harvest from the Ecosystem pool
   - All HWP carbon is oxidized in the year of harvest
   - Zero net flux in the HWP pool

2. HWP Carbon Accounting
   - Choose a tier
   - Choose an approach

Methods: IPCC HWP

<u>Three Tiers</u>

- Tier 1: Coarse assumptions, UN-FAO data
- Tier 2: Coarse assumptions, area specific data
- Tier 3: Complex, detailed, area specific methods

Methods: IPCC HWP

Three Tiers

- Tier 1: Coarse assumptions, UN-FAO data
- Tier 2: Coarse assumptions, area specific data
- Tier 3: Complex, detailed, area specific methods
  - Single approach
  - More complex decay functions
  - Detailed tracking over many years
  - Account for exported products
  - Potentially information from outside the area
  - Interaction with other sectors (waste, energy, etc.)

Methods: IPCC HWP

Three Approaches

1. Stock change methods
   - All HWP consumed in the area, regardless of origin
   - Imports are included, exports are excluded
2. Production methods
   - All HWP produced from timber harvested in the area
   - Exports are included, imports are excluded
3. Atmospheric flow methods
   - Direct estimation of annual atmospheric flux
4. Combined methods

Methods: IPCC HWP

Three Approaches

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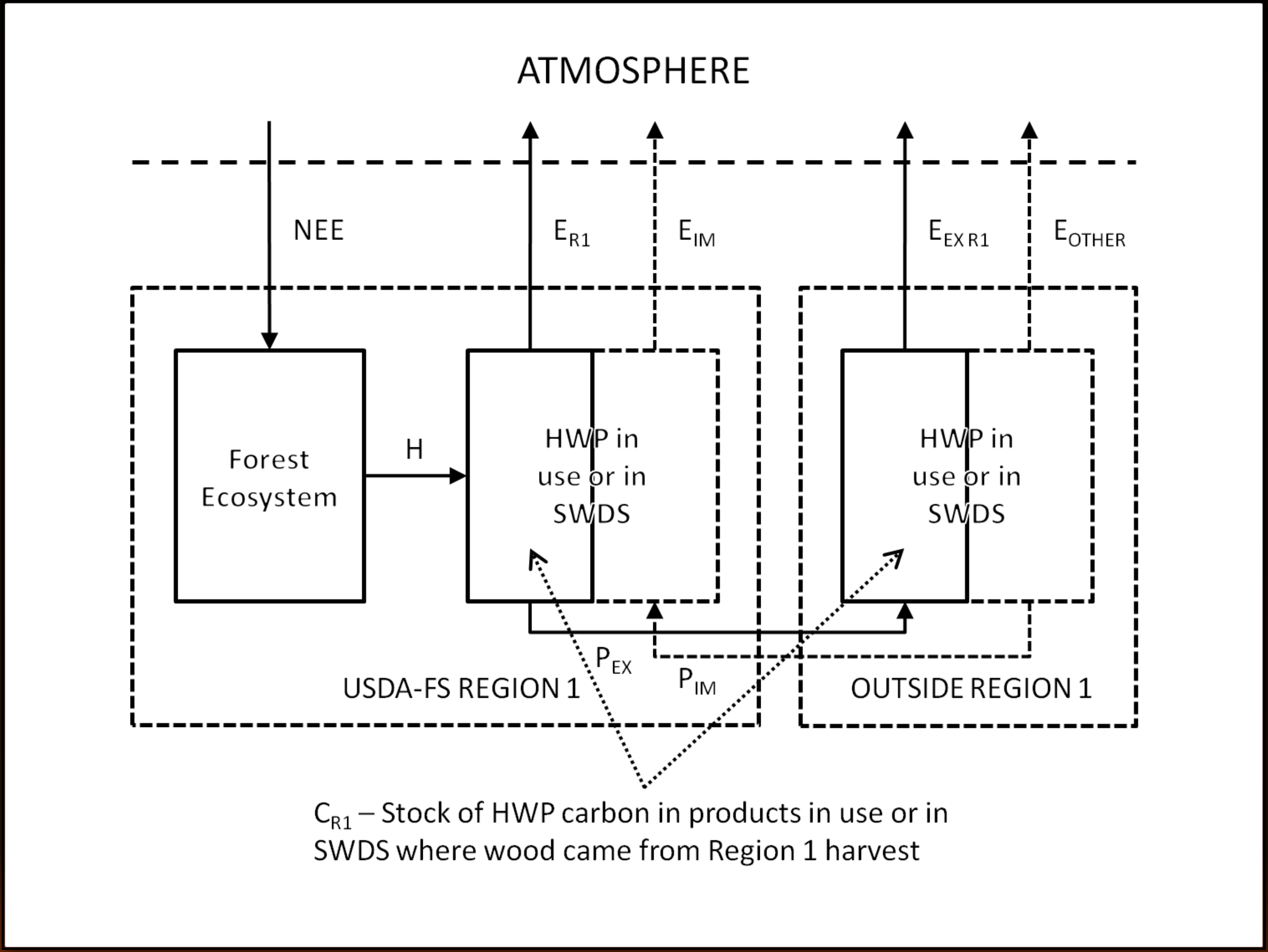
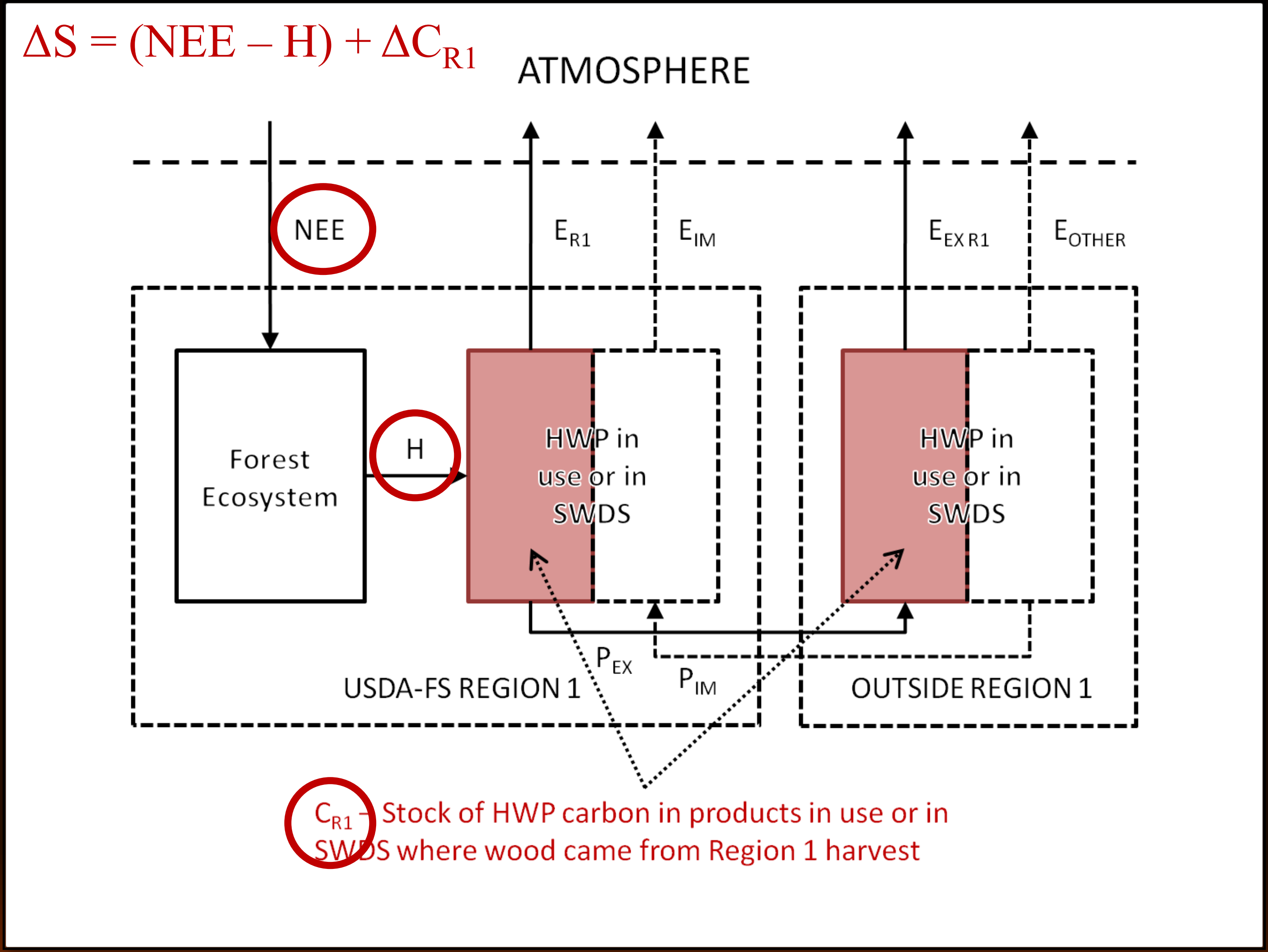
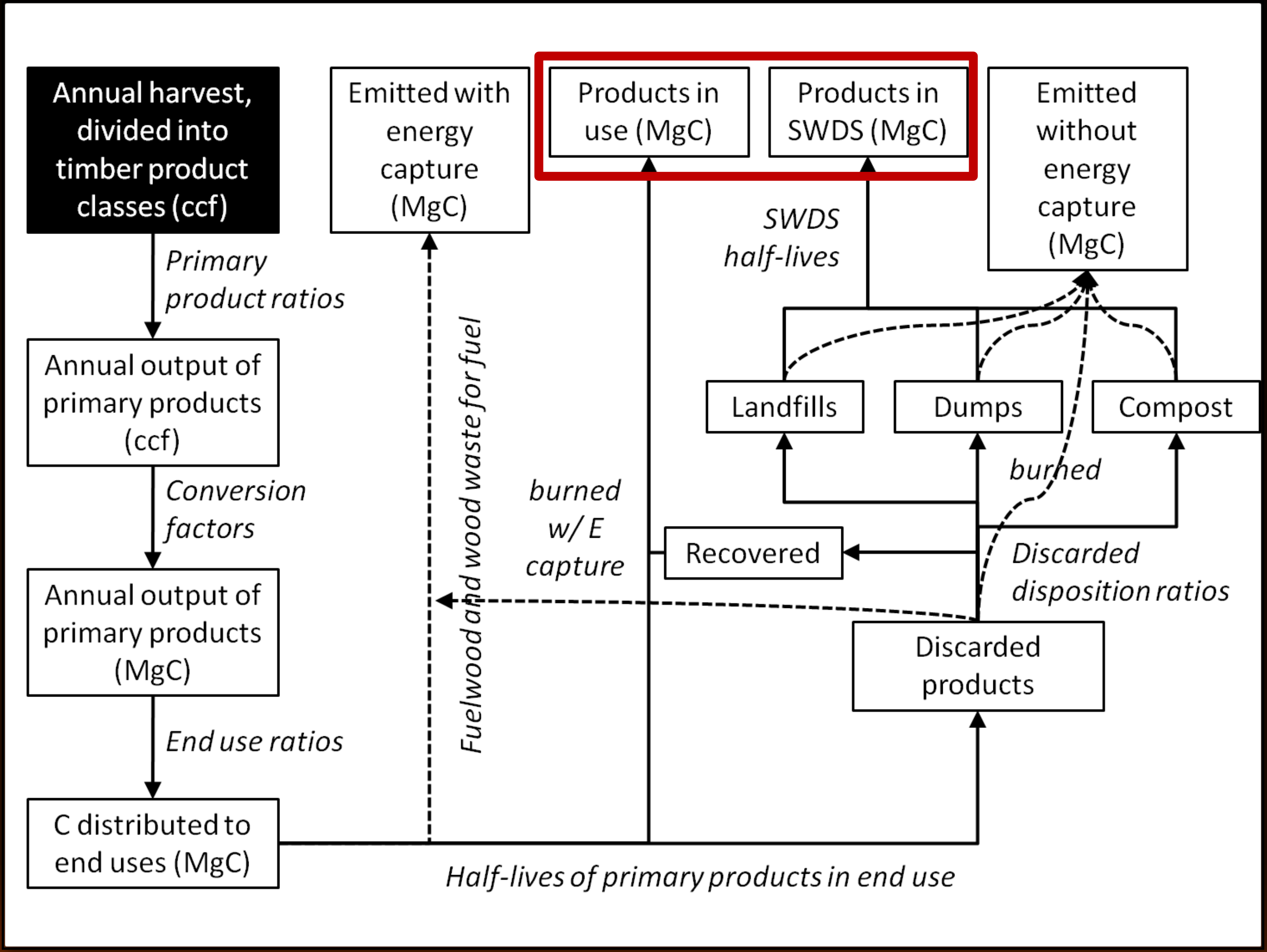
Methods: Production Approach



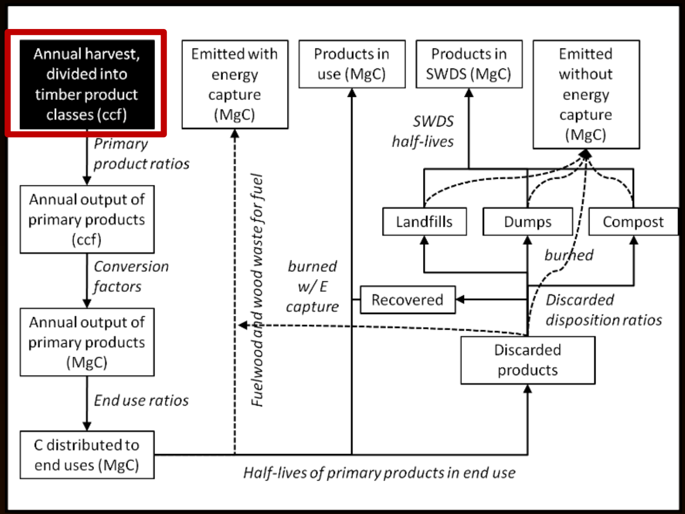
Methods: Production Approach

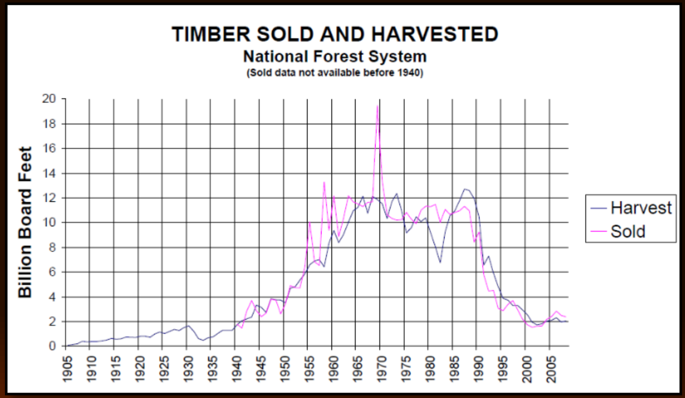


Methods: Calculations



Methods: Data Sources

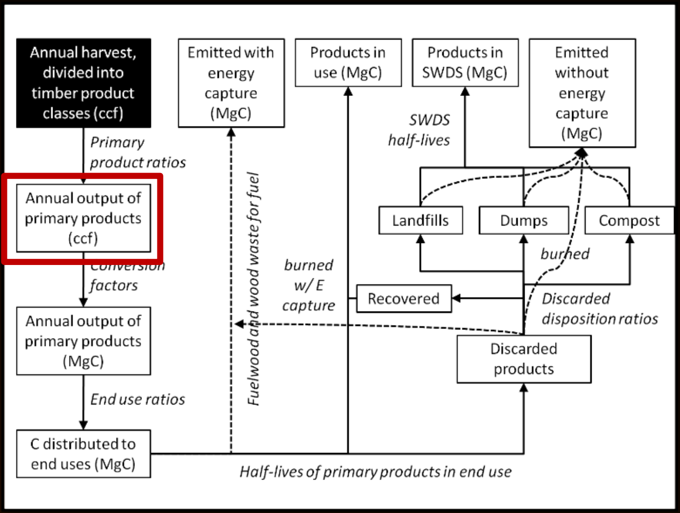


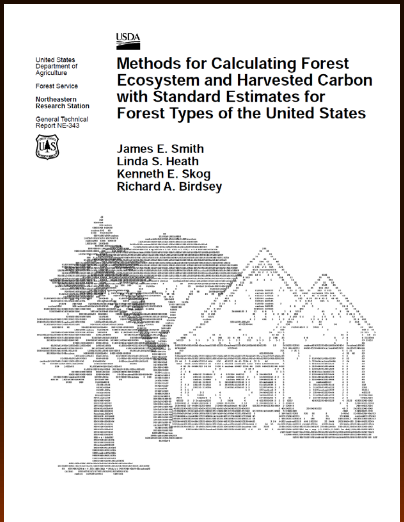


<u>Harvest Data</u>

- Archived harvest records
- Online cut-sold reports
- Timber product ratios (Skog & Nicholson 1998)
- Softwood v. Hardwood
- Timber product examples:
  - Sawtimber
  - Pulpwood
  - Fuelwood
  - Post and pole
  - “Non-saw”
  - Christmas trees

Methods: Data Sources




USDA

United States Department of Agriculture

Forest Service

Northeastern Research Station

General Technical Report NE-343

Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States

James E. Smith
Linda S. Heath
Kenneth E. Skog
Richard A. Birdsey

<u>Primary products</u>

- Market records
- Production reporting
- Primary product ratios (Smith et al. 2005)
- Examples:
  - Lumber
  - Pulp
  - Plywood/OSB/NS-panels
  - Mill residue
  - Poles
  - Fuelwood

Methods: Data Sources

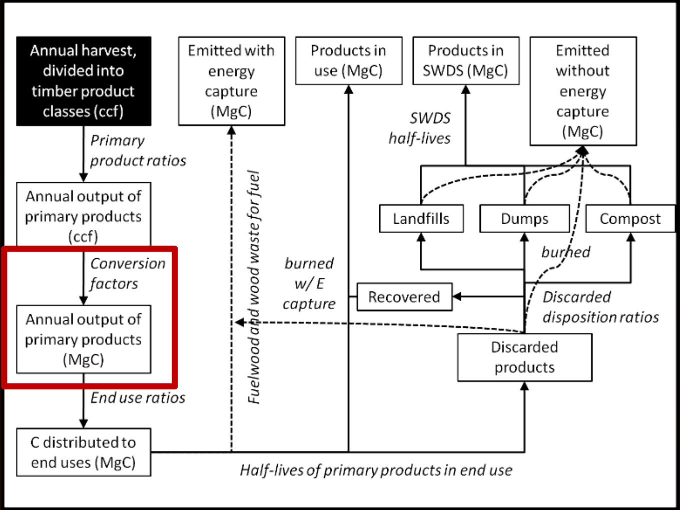


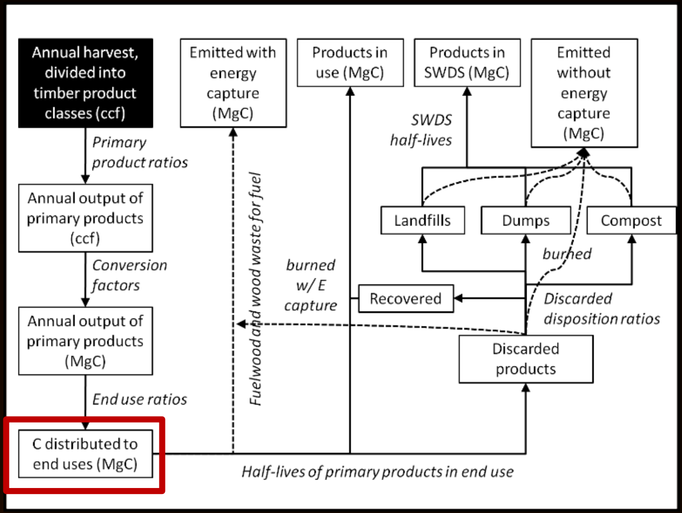
Table 2—Conversion factors used in this analysis.

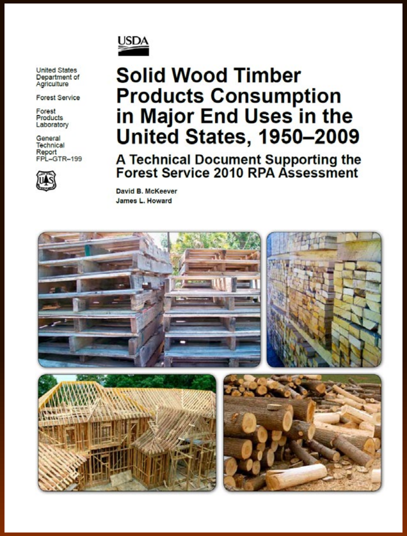
Conversion	Units
2.2	ccf per mbf, timber harvest
1.75 to 2.56	ccf per mbf, timber products
33 to 42	lbs per cubic foot, primary products
2204.6	lbs per Mg
0.95 to 1.0	Mg wood fiber per Mg product
0.5	Mg carbon per dry Mg wood fiber
0.711 to 0.919	MgC per ccf, primary products

Convert Products to Carbon

- Empirical conversions
- Industry "standards"
- Accepted conversions
- Regional and local conversions
- Smith et al. 2005, wood to C
- Examples:
  - IPCC
  - UN-FAO
  - USFS
  - Industry standards
  - LCA calculations
  - Etc., etc.

Methods: Data Sources





End use distribution

- Market records
- Production reporting
- End use ratios (S&N 1998; McKeever 2009)
- Examples:
  - Lumber, single family housing
  - Lumber, multifamily housing
  - Lumber, manufactured housing
  - Lumber, residential r and r
  - Lumber, nonresidential buildings
  - Lumber, other building

End use categories

Softwood lumber,new housing,single family
Softwood lumber,new housing,multifamily
Softwood lumber,new housing,manufactured housing
Softwood lumber,residential r and r,n/a
Softwood lumber,new nonresidential,new nonres buildings
Softwood lumber,new nonresidential,other
Softwood lumber,rail and railcar,n/a
Softwood lumber,manufacturing,furniture
Softwood lumber,manufacturing,other manufacturing
Softwood lumber,packaging and shipping,n/a
Softwood lumber,other,n/a
Softwood lumber,default,n/a
Softwood lumber,default,n/a
Softwood lumber,default,n/a
Softwood lumber,default,n/a
Softwood plywood,new housing,single family
Softwood plywood,new housing,multifamily
Softwood plywood,new housing,manufactured housing
Softwood plywood,residential r and r,n/a
Softwood plywood,new nonresidential,new nonres buildings
Softwood plywood,new nonresidential,other
Softwood plywood,rail and railcar,n/a
Softwood plywood,manufacturing,furniture
Softwood plywood,manufacturing,other manufacturing
Softwood plywood,packaging and shipping,n/a
Softwood plywood,other,n/a
Softwood plywood,default,n/a
Softwood plywood,default,n/a
Softwood plywood,default,n/a
Softwood plywood,default,n/a
Softwood misc products,n/a,n/a
Softwood exported logs,n/a,n/a
Softwood mill residue, pulp,pulp and paper,n/a
Softwood mill residue, OSB,new housing,single family
Softwood mill residue, OSB,new housing,multifamily
Softwood mill residue, OSB,new housing,manufactured housing
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Softwood mill residue, non-structural panels,default,n/a
Softwood mill residue, non-structural panels,default,n/a
Softwood mill residue, non-structural panels,default,n/a
Softwood mill residue, non-structural panels,default,n/a
Softwood mill residue, fuel, unused,fuel,n/a
Softwood other ,n/a,n/a
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Hardwood plywood,n/a,n/a
Hardwood misc products,n/a,n/a
Hardwood exported logs,n/a,n/a
Hardwood mill residue, pulp,pulp and paper,n/a
Hardwood mill residue, OSB,new housing,single family
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Hardwood mill residue, OSB,residential r and r,n/a
Hardwood mill residue, OSB,new nonresidential,new nonres buildings
Hardwood mill residue, OSB,new nonresidential,other
Hardwood mill residue, OSB,rail and railcar,n/a
Hardwood mill residue, OSB,manufacturing,furniture
Hardwood mill residue, OSB,manufacturing,other manufacturing
Hardwood mill residue, OSB,packaging and shipping,n/a
Hardwood mill residue, OSB,other,n/a
Hardwood mill residue, OSB,default,n/a
Hardwood mill residue, OSB,default,n/a
Hardwood mill residue, OSB,default,n/a
Hardwood mill residue, OSB,default,n/a
Hardwood mill residue, non-structural panels,new housing,single family
Hardwood mill residue, non-structural panels,new housing,multifamily
Hardwood mill residue, non-structural panels,new housing,manufactured housing
Hardwood mill residue, non-structural panels,residential r and r,n/a
Hardwood mill residue, non-structural panels,new nonresidential,new nonres buildings
Hardwood mill residue, non-structural panels,new nonresidential,other
Hardwood mill residue, non-structural panels,rail and railcar,n/a
Hardwood mill residue, non-structural panels,manufacturing,furniture
Hardwood mill residue, non-structural panels,manufacturing,other manufacturing
Hardwood mill residue, non-structural panels,packaging and shipping,n/a
Hardwood mill residue, non-structural panels,other,n/a
Hardwood mill residue, non-structural panels,default,n/a
Hardwood mill residue, non-structural panels,default,n/a
Hardwood mill residue, non-structural panels,default,n/a
Hardwood mill residue, non-structural panels,default,n/a
Hardwood mill residue, fuel, unused,fuel,n/a
Hardwood other ,n/a,n/a
Softwood pulpwood in woodpulp,pulp and paper,n/a
Softwood pulpwood in OSB,new housing,single family
Ties, softwood,n/a,n/a
Ties, hardwood,n/a,n/a
Misc., softwood, convert.,n/a,n/a
Misc., hardwood, convert.,n/a,n/a
Christmas trees,n/a,n/a
Misc., softwood, non-convert.,n/a,n/a
Misc. hardwood, non-convert.,n/a,n/a
Cull, softwood,n/a,n/a
Cull, hardwood,n/a,n/a
Small roundwood, softwood,n/a,n/a
Small roundwood, hardwood,n/a,n/a
Other,n/a,n/a

Softwood pulpwood in OSB,new housing,multifamily
Softwood pulpwood in OSB,new housing,manufactured housing
Softwood pulpwood in OSB,residential r and r,n/a
Softwood pulpwood in OSB,new nonresidential,new nonres buildings
Softwood pulpwood in OSB,new nonresidential,other
Softwood pulpwood in OSB,rail and railcar,n/a
Softwood pulpwood in OSB,manufacturing,furniture
Softwood pulpwood in OSB,manufacturing,other manufacturing
Softwood pulpwood in OSB,packaging and shipping,n/a
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Softwood pulpwood in OSB,default,n/a
Softwood pulpwood in OSB,default,n/a
Softwood pulpwood in OSB,default,n/a
Softwood pulpwood in OSB,default,n/a
Softwood pulpwood in Non structural panels,new housing,single family
Softwood pulpwood in Non structural panels,new housing,multifamily
Softwood pulpwood in Non structural panels,new housing,manufactured housing
Softwood pulpwood in Non structural panels,residential r and r,n/a
Softwood pulpwood in Non structural panels,new nonresidential,new nonres buildings
Softwood pulpwood in Non structural panels,new nonresidential,other
Softwood pulpwood in Non structural panels,rail and railcar,n/a
Softwood pulpwood in Non structural panels,manufacturing,furniture
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Softwood pulpwood in Non structural panels,packaging and shipping,n/a
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Softwood pulpwood in Non structural panels,default,n/a
Softwood pulpwood in Exported pulpwood,pulp and paper,n/a
Softwood pulpwood in fuel, unused,fuel,n/a
Hardwood pulpwood in woodpulp,pulp and paper,n/a
Hardwood pulpwood in OSB,new housing,single family
Hardwood pulpwood in OSB,new housing,multifamily
Hardwood pulpwood in OSB,new housing,manufactured housing
Hardwood pulpwood in OSB,residential r and r,n/a
Hardwood pulpwood in OSB,new nonresidential,new nonres buildings
Hardwood pulpwood in OSB,new nonresidential,other
Hardwood pulpwood in OSB,rail and railcar,n/a
Hardwood pulpwood in OSB,manufacturing,furniture
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Hardwood pulpwood in Non structural panels,new nonresidential,new nonres buildings
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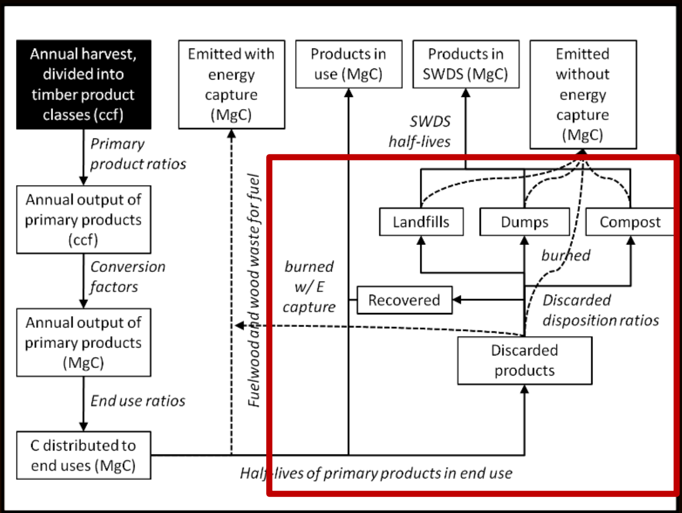
Hardwood pulpwood in Non structural panels,other,n/a
Hardwood pulpwood in Non structural panels,default,n/a
Hardwood pulpwood in Non structural panels,default,n/a
Hardwood pulpwood in Non structural panels,default,n/a
Hardwood pulpwood in Non structural panels,default,n/a
Hardwood pulpwood in Exported pulpwood,pulp and paper,n/a
Hardwood pulpwood in fuel, unused,fuel,n/a
Poles, softwood,n/a,n/a
Poles, hardwood,n/a,n/a
Posts, softwood,n/a,n/a
Posts, hardwood,n/a,n/a
Fuelwood, softwood,n/a,n/a
Fueldwood, hardwood,n/a,n/a
Non-saw, softwood,n/a,n/a
Non-saw, hardwood,n/a,n/a

Methods: Data Sources



Decay functions

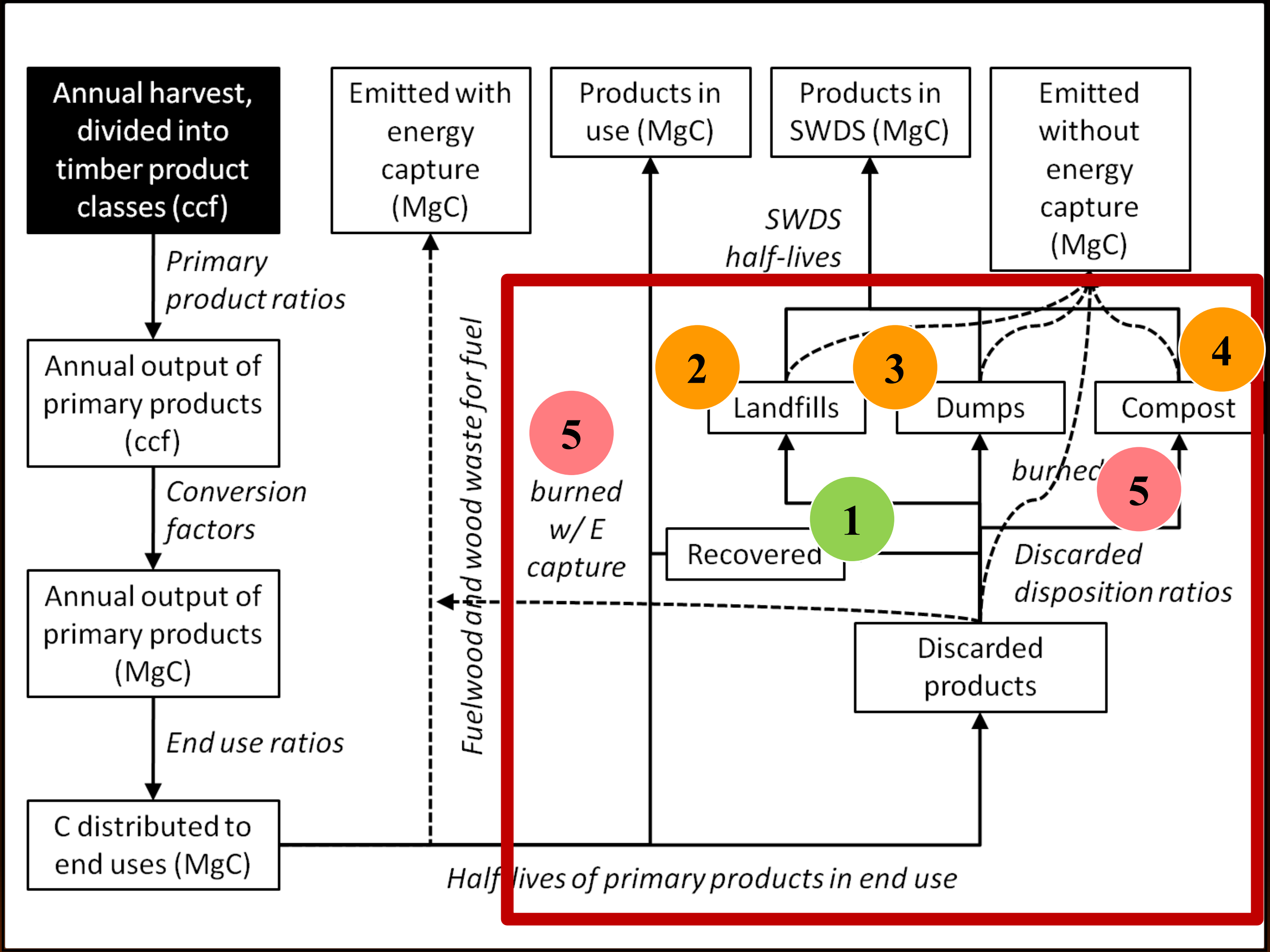
- Decay 1: End use → SWDS
- Decay 2: SWDS → Emissions
- Decay functions:
  - Empirical estimates
  - IPCC/EPA estimates (Skog 2008)
  - Area specific information

Table 4. — Initial estimates of half-life parameters for end uses (before validation/calibration).

Parameter	Definition	Value
HL_{H1}	Half-life of solidwood in single-family housing 1920 and before	75 years
HL_{H2}	Half-life of solidwood in single-family housing – 1921 to 1939 (years)[a]	80 years
F_H	Increase in half-life for each 20 year period after 1921 to 1939 (years)	5 years
F_{MF}	Ratio of half-life for solidwood in multifamily housing to half-life in single family housing	0.625
F_{AR}	Ratio of half-life for solidwood in alterations and repair of housing to half-life for single-family housing	0.3215
HL_{OTH}	Half-life for solidwood in all other end uses (years)[b]	30 years
HL_P	Half-life for paper in all end uses (years)[b]	2 years

[a] U.S. housing half-life: Winistorfer et al. 2005; Athena Institute 2004.
[b] Other solidwood and paper half-life: IPCC 2006b.

Methods: Calculations



background → **methods** → example → discussion

Methods: The Meaning of "Year"

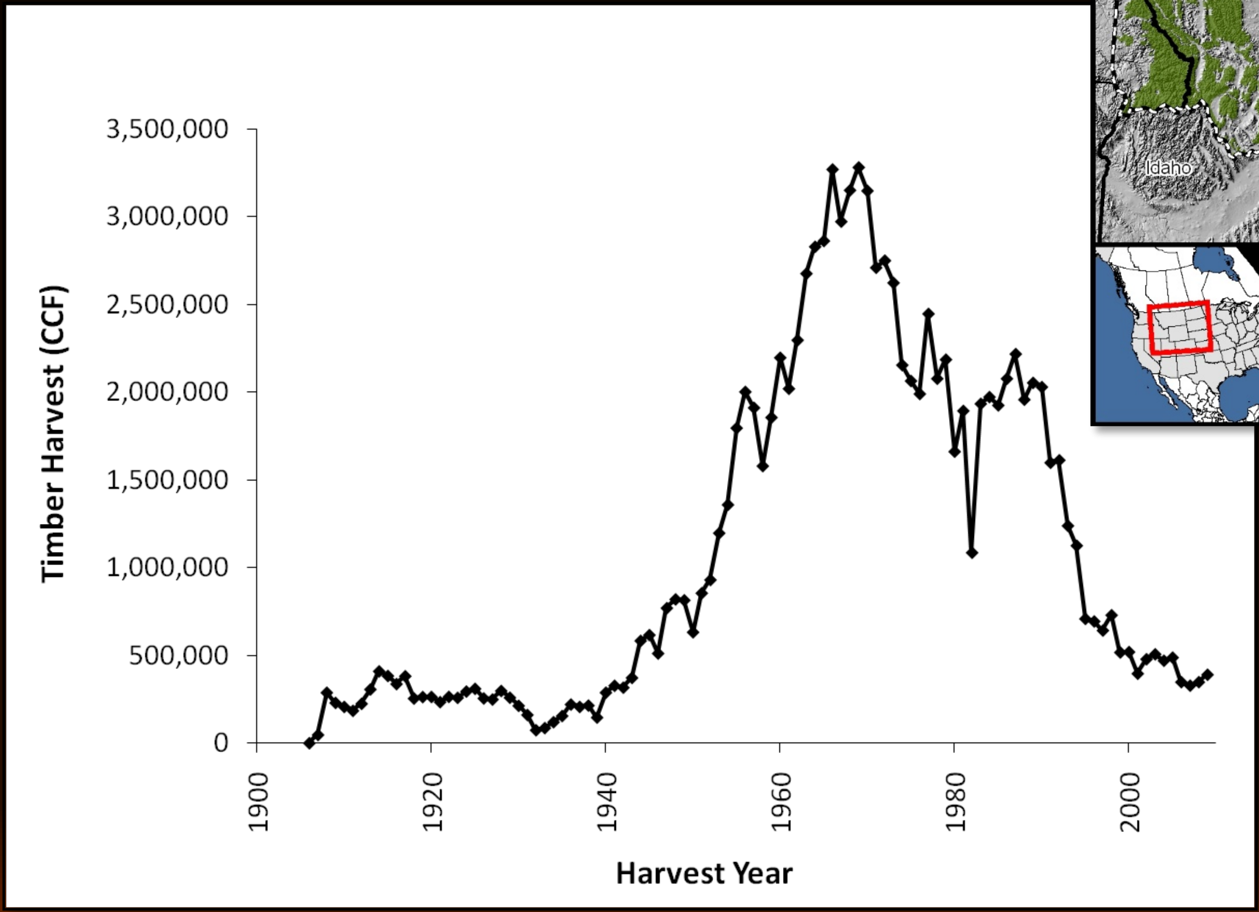
- Vintage year: The year the carbon in the HWP pool was harvested
- Inventory year: The year of the stock calculation, including C from all vintage years
- Stock change (flux): The difference in stocks between two inventory years, typically annual
- Example:
  - "Very little HWP carbon from vintage year 1960 remains in the HWP pool in inventory year 2017, but flux into the pool was very high that year."

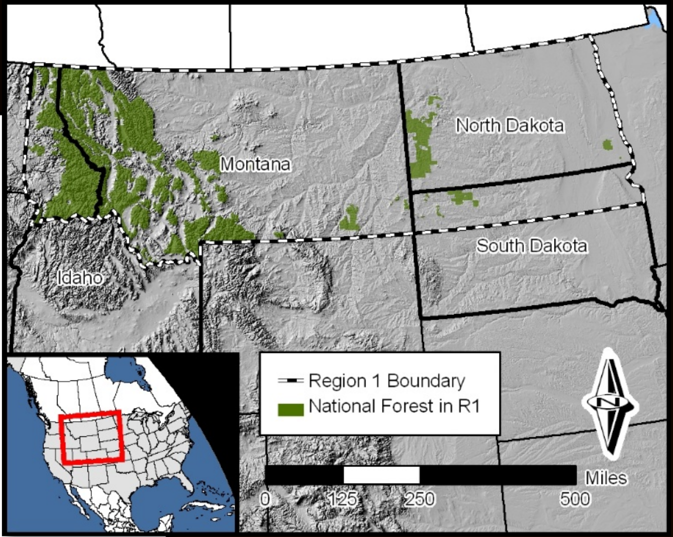
Methods: Loose Ends

- Landfill fixed carbon
  - 44% to 77% HWP carbon in landfills does not decay
- Bark is not included. What are the options?
  - Ignore bark (assume net zero effect)
  - Use bark expansion factors
    - Assume 100% emissions in year of harvest
    - Track as a "product"
- Loss in Use
  - 8% carbon "loss in use" when it enters the pool
  - Emitted in year of harvest

Example: USFS Region 1

- Region 1 Timber Harvest





Example: USFS Region 1

- Region 1 Timber Harvest

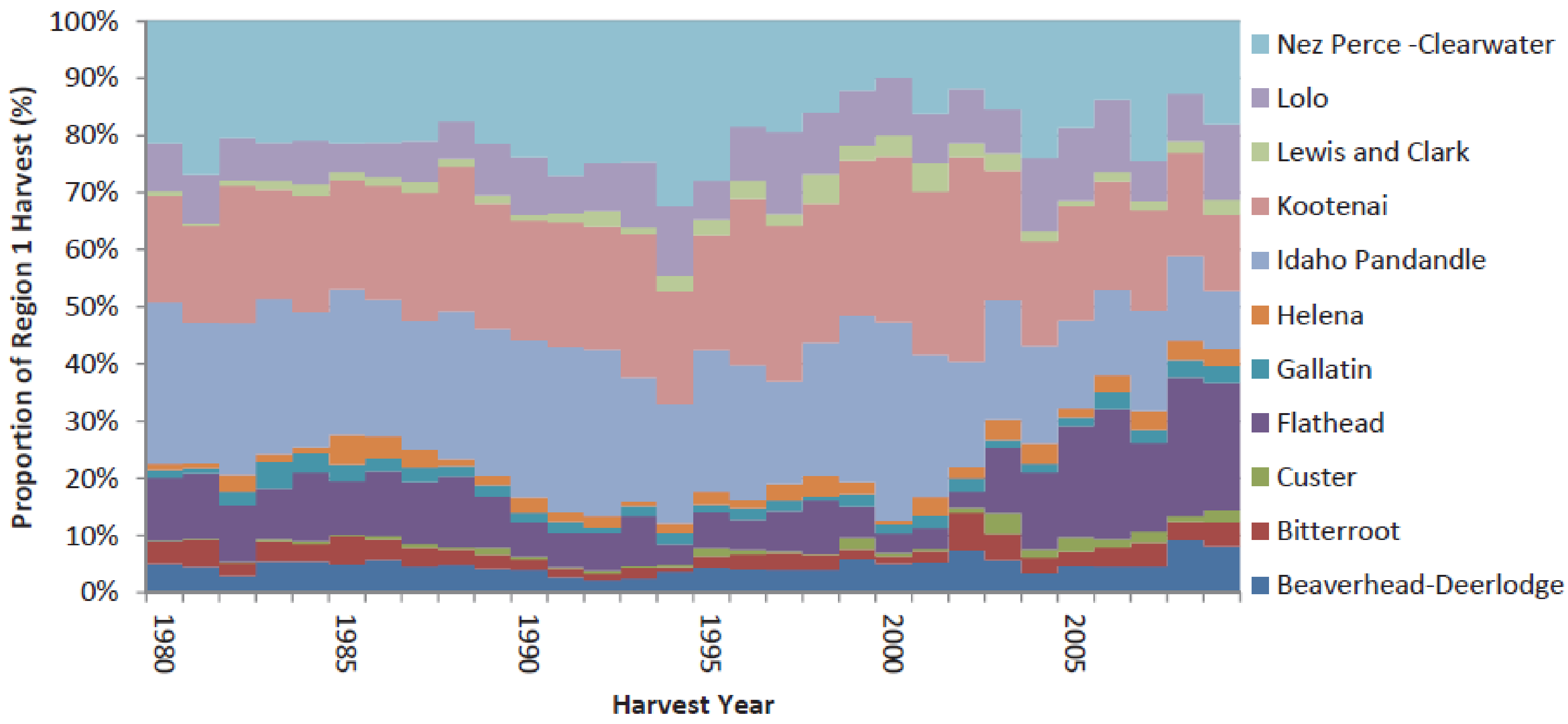
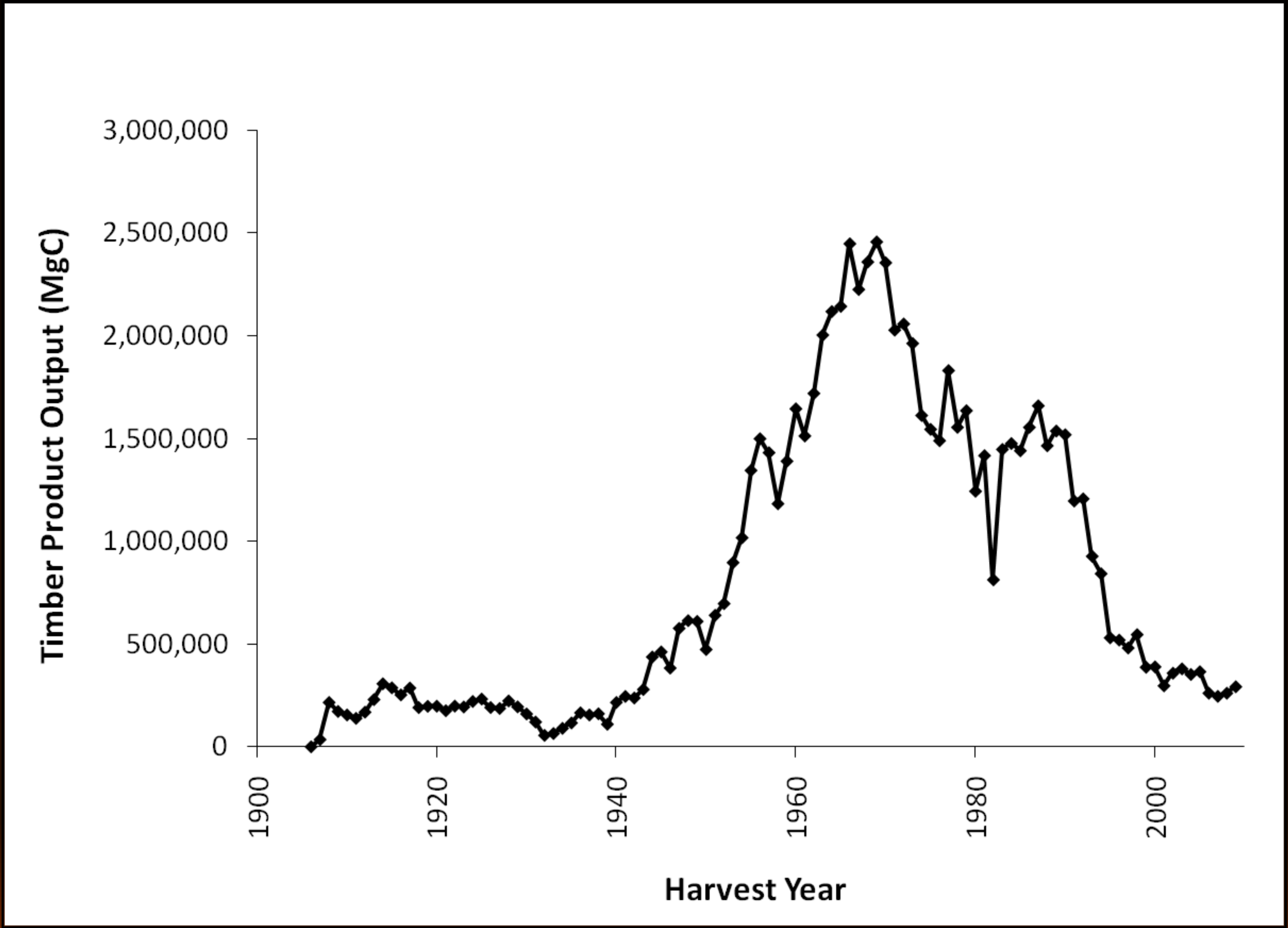


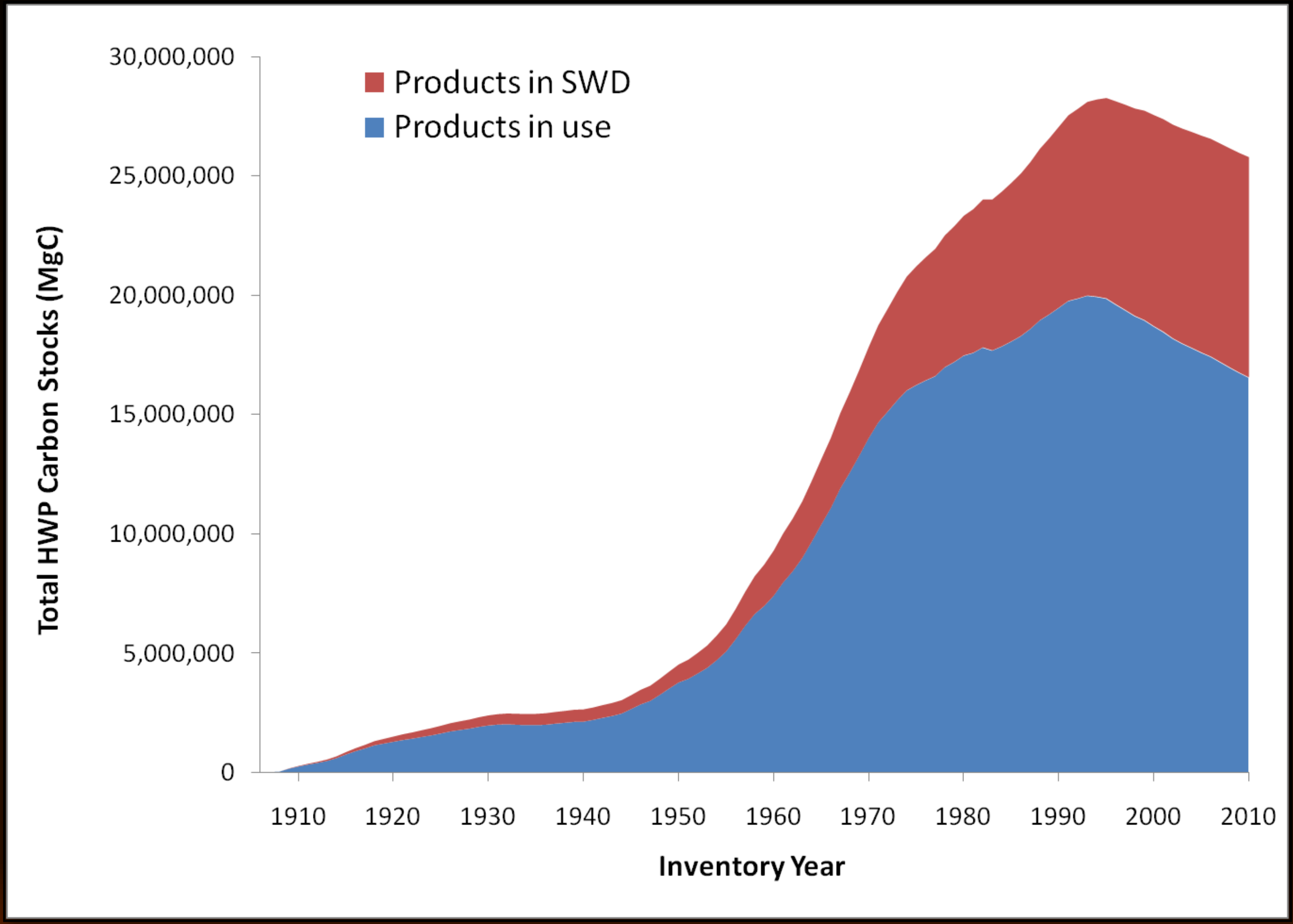
Figure 9—The proportion of the total Northern Region harvest attributable to each national forest in the Region, 1980 to 2009.

background → *methods* → ***example*** → *discussion*

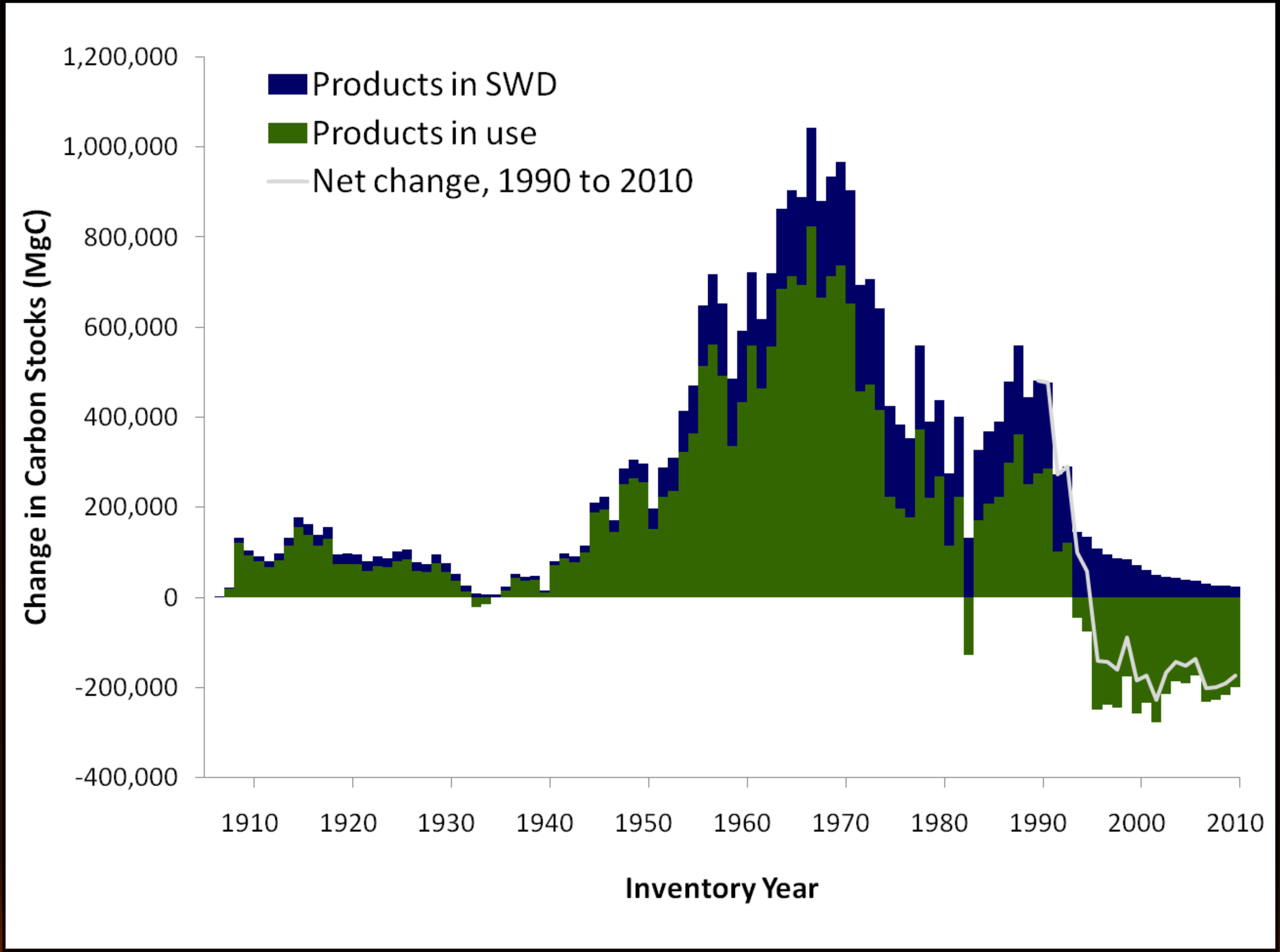
Example: Output in MgC



Example: Cumulative C in HWP



Example: Net Δ in HWP C Stocks



background → *methods* → ***example*** → *discussion*

Forest C Pool = Ecosystem + HWP

Pool/Flux	Ecosystem +	Ecosystem -
HWP +	↑ ↑	↓ ↑
HWP -	↑ ↓	↓ ↓

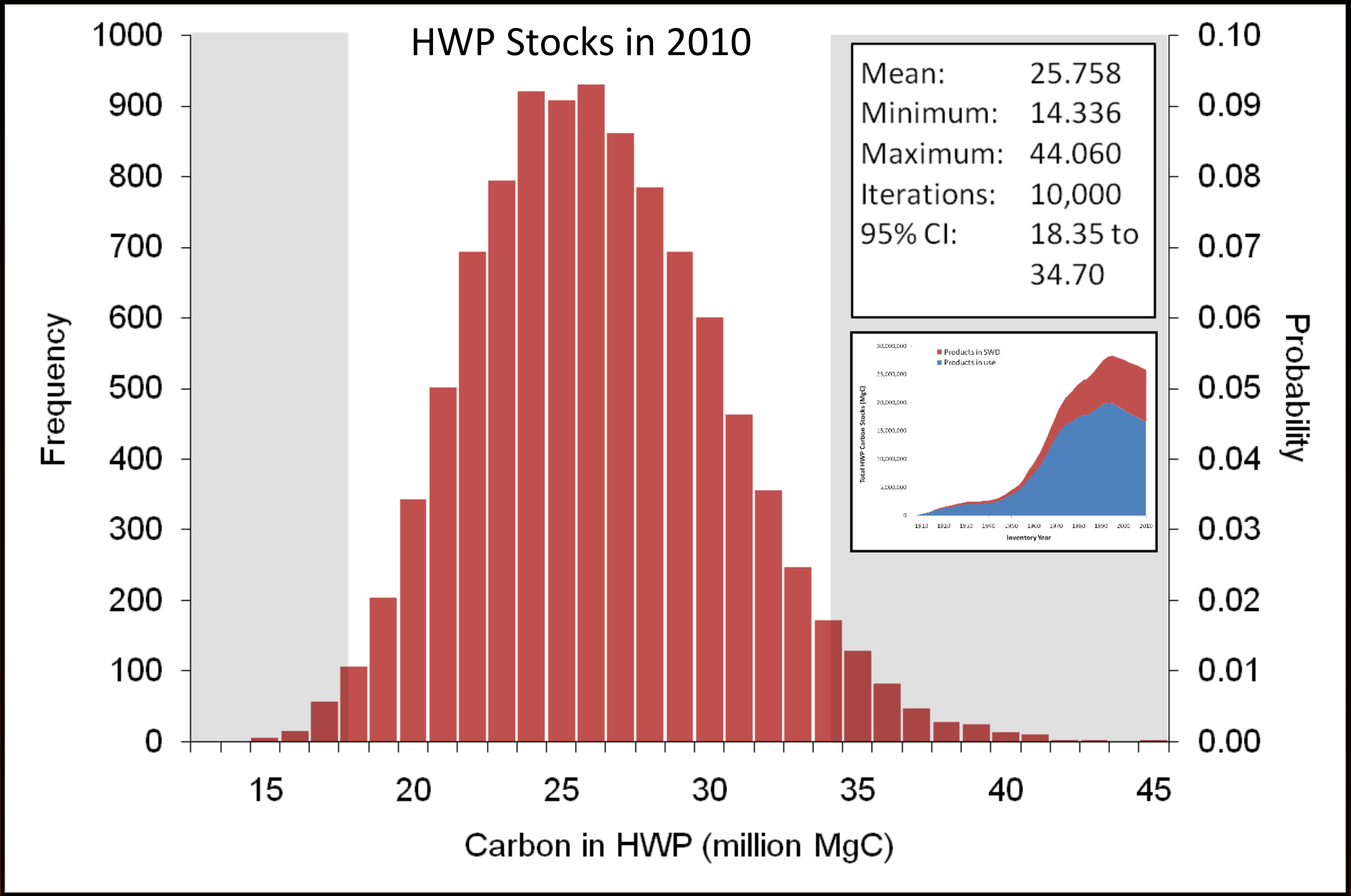
Methods: Uncertainty Analysis

- Identify sources of uncertainty
- Set distributions
- Monte Carlo Simulation
- Quantify effects of uncertainty on outputs

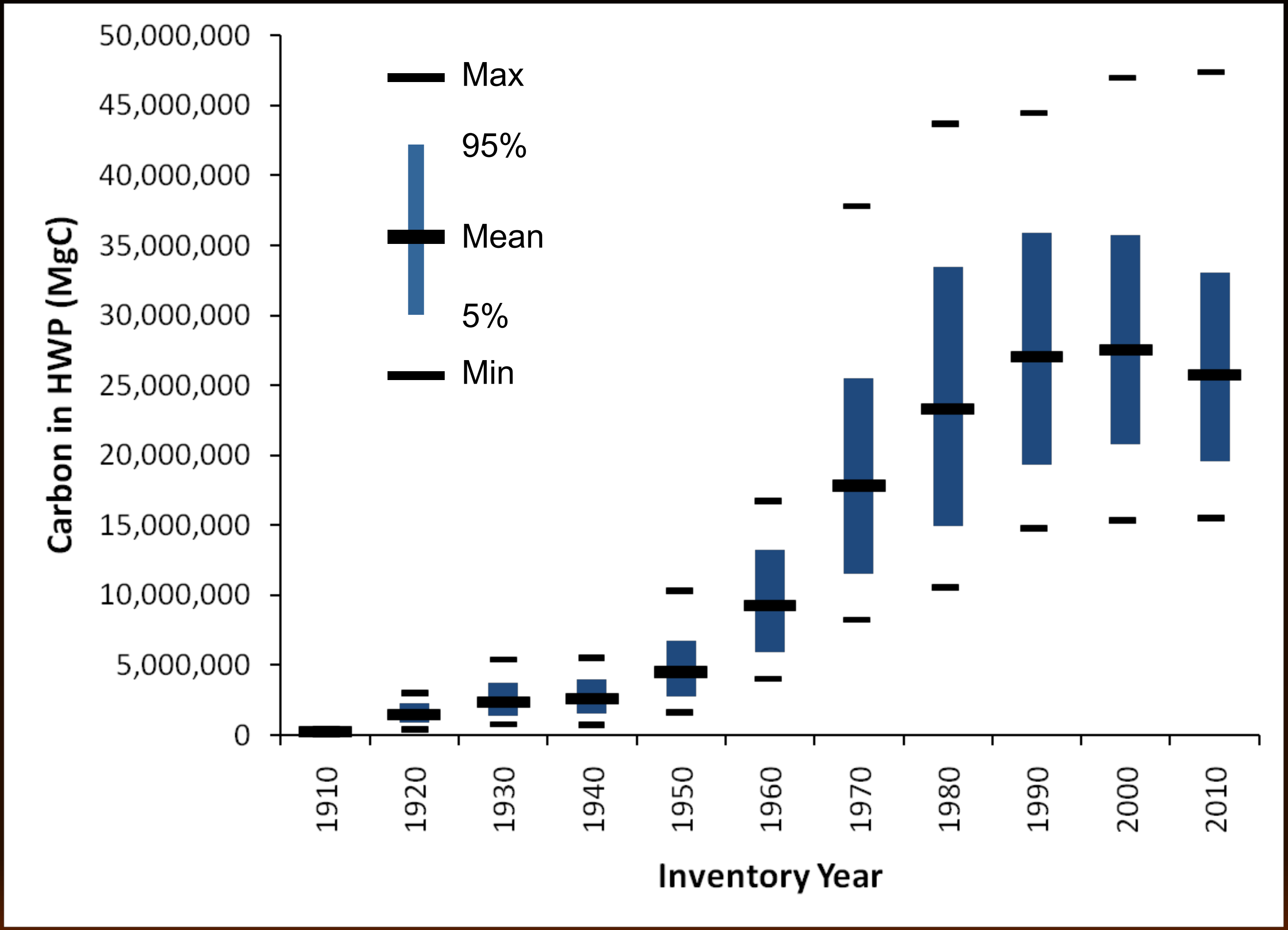
Example: Uncertainty Analysis

Source of Uncertainty	Specific Factor	Years	Relevant products	90% CI	Correlation
Conversion factors	mbf:ccf	1906 to 1979	Timber products	±30%	no
	mbf:ccf	1980 to 2009	Timber products	±15%	no
	ccf:MgC	1906 to 2009	Primary products	±5%	no
Reported harvest	Harvest in mbf	1906 to 1945	Timber products	±30%	yes
	Harvest in mbf	1946 to 1979	Timber products	±20%	yes
	Harvest in mbf or ccf	1980 to 2009	Timber products	±15%	yes
Product distribution	Roundwood to softwood sawtimber	1906 to 1979	Timber products	±30%	no
	Roundwood to softwood sawtimber	1980 to 2009	Timber products	±15%	no
	Softwood sawtimber to lumber	1906 to 1949	Timber products	±30%	no
	Softwood sawtimber to lumber	1950 to 1979	Timber products	±20%	no
	Softwood sawtimber to lumber	1980 to 2009	Timber products	±15%	no
	Lumber going to new housing	1906 to 2009	Primary products	±15%	no
	Panels going to new housing	1906 to 2009	Primary products	±15%	no
	Residues going to pulp	1906 to 2009	Primary products	±15%	no
Product decay	Product half life	1906 to 2009	All end-use	±15%	yes
	Fraction of discards going to landfills	1906 to 2009	Discarded	±15%	yes
	Landfill decay limits	1906 to 2009	Landfilled	±15%	yes
	Landfill half life	1906 to 2009	Landfilled	±15%	yes

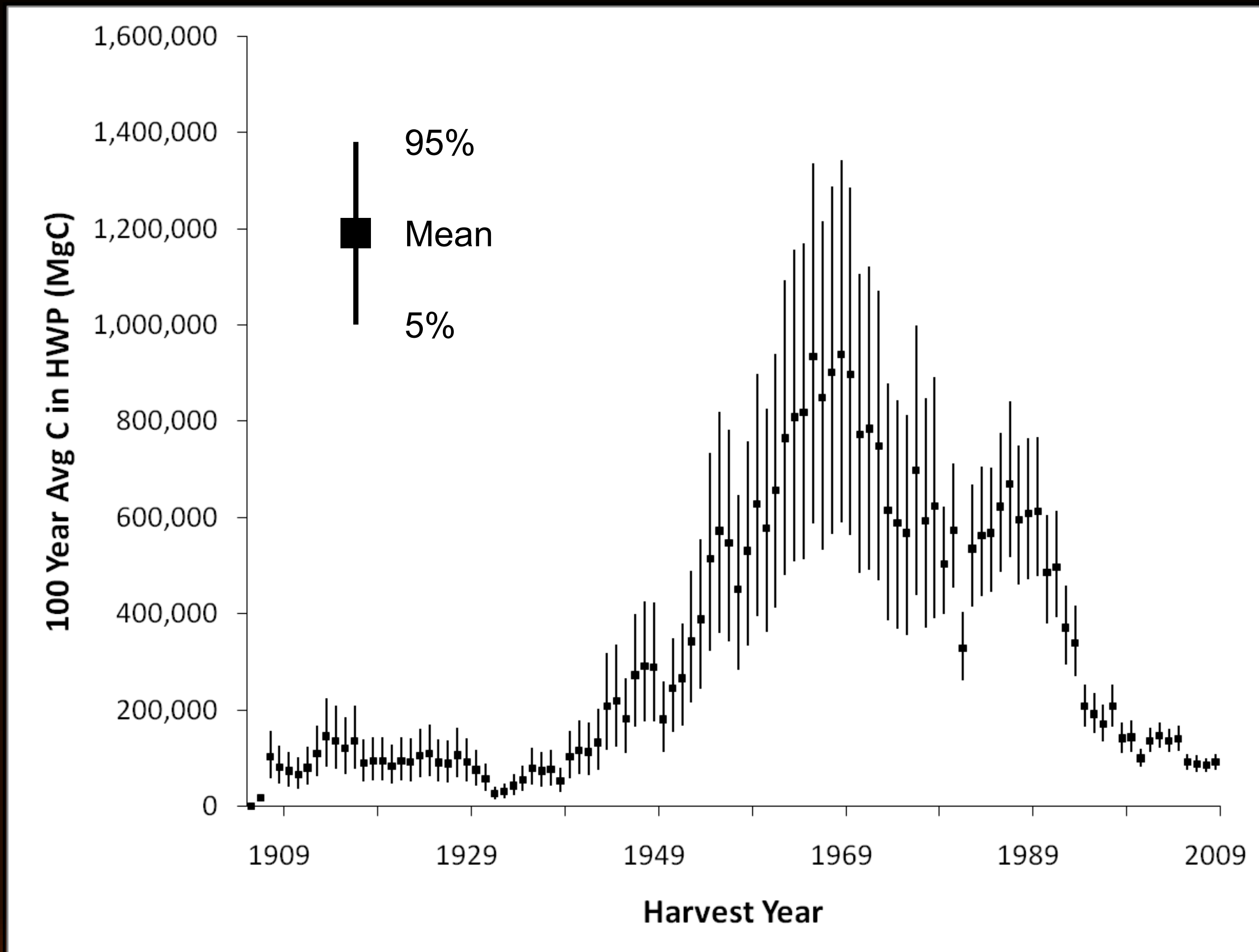
Example: Uncertainty Analysis



Example: Uncertainty Analysis



Example: Uncertainty Analysis



Take Home

- HWP is an important forest carbon pool in U.S.
- Choose an appropriate accounting method
- Tradeoffs between alternative approaches
- Inventory methods:
  - Can be effective at multiple scales (nation, state, etc.)
  - Do not provide a complete picture of indirect effects
  - But are useful and achievable
- Quantifying uncertainty is an important part of carbon accounting

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QUESTIONS & DISCUSSION

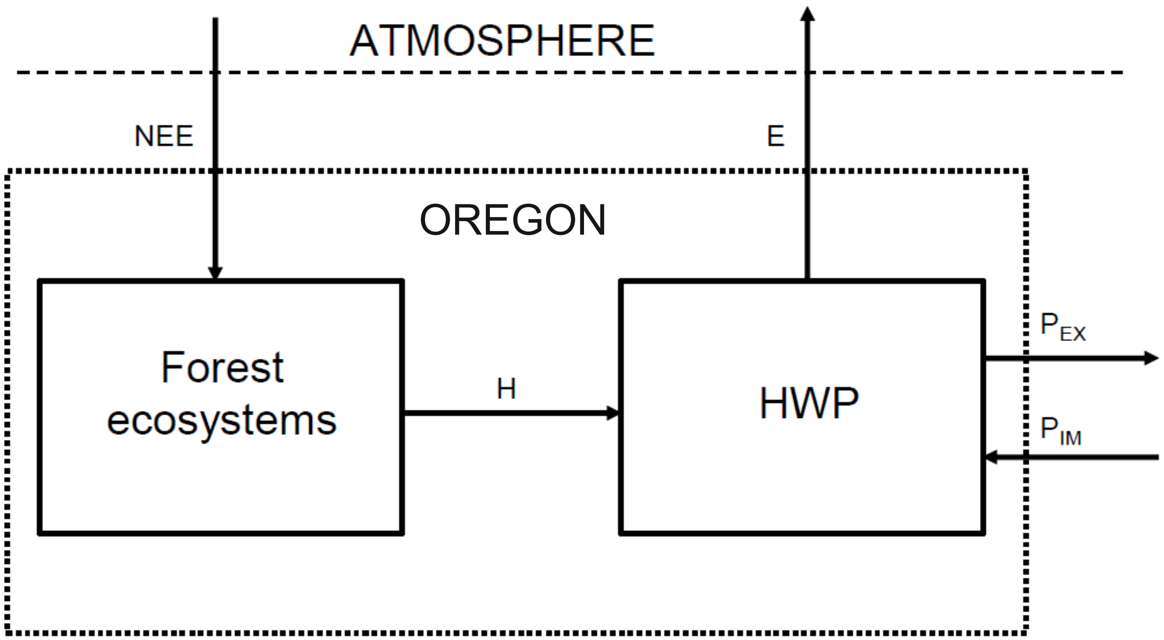
Additional slides

Methods: Data Sources

- Harvest Data
  - 1906-1979 Archived harvest data
  - 1980-2010 Online cut-sold reports
- Timber product output (State, UM-BBER, others)
- Timber product ratios (Skog & Nicholson 1998)
- Primary product ratios (Smith et al. 2005)
- Wood to carbon estimates (Smith et al. 2005)
- End use ratios (S&N 1998; McKeever 2009)
- Disposition and half-life data (Skog 2008)

Methods: IPCC HWP

Figure 3a.1.1 Carbon flows and stocks associated with forests and harvested wood products (HWP) to illustrate the Stock Change and Atmospheric Flow Accounting[2] Approaches.

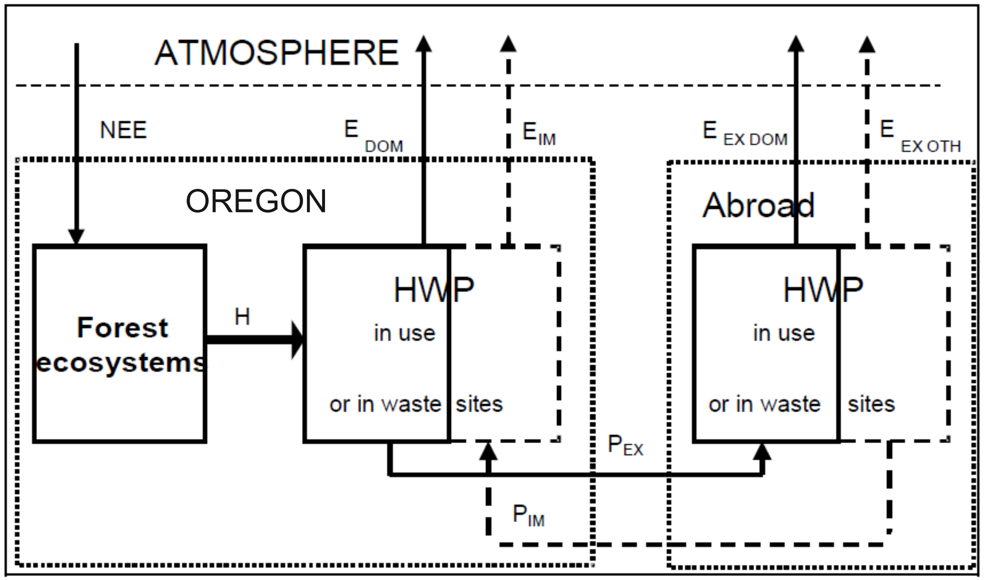


Variable definitions:

NEE = net ecosystem exchange
H = harvested wood transported from forests
E = emissions from HWP within country borders
P_{EX} = exports of HWP including roundwood, wood-based waste and refined products
P_{IM} = imports of HWP including roundwood, wood-based waste and refined products

Methods: IPCC HWP

Figure 3a.1.2 Carbon flows and stocks associated with forests and harvested wood products (HWP) to illustrate the Production Accounting Approach.



Variable definitions:

NEE = net ecosystem exchange

H = harvested wood transported from forests

E_{DOM} = emissions from HWP in own country made from wood harvested from domestic forests

$E_{EX\ DOM}$ = emissions from HWP in other countries made from wood exported abroad that were made from wood harvested from own country's forests

E_{IM} = emission from imported HWP in own country

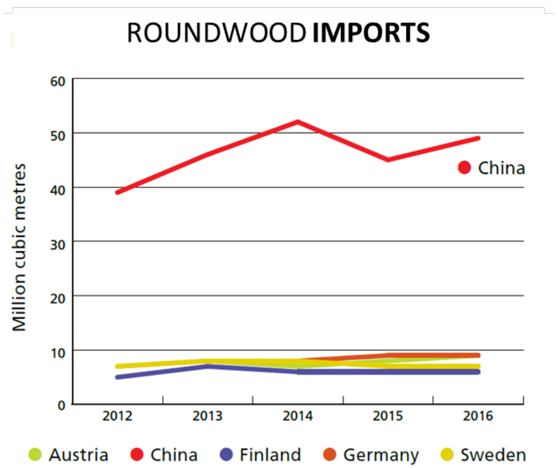
$E_{EX\ OTH}$ = emissions from HWP in other countries made from wood harvested in other countries

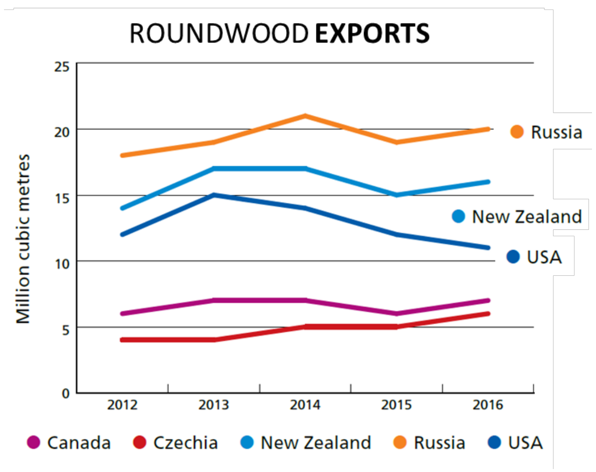
P_{EX} = exports of HWP including roundwood, wood-based waste and refined products

P_{IM} = imports of HWP including roundwood, wood-based waste and refined products

Methods: IPCC HWP

- How important are imports and exports?





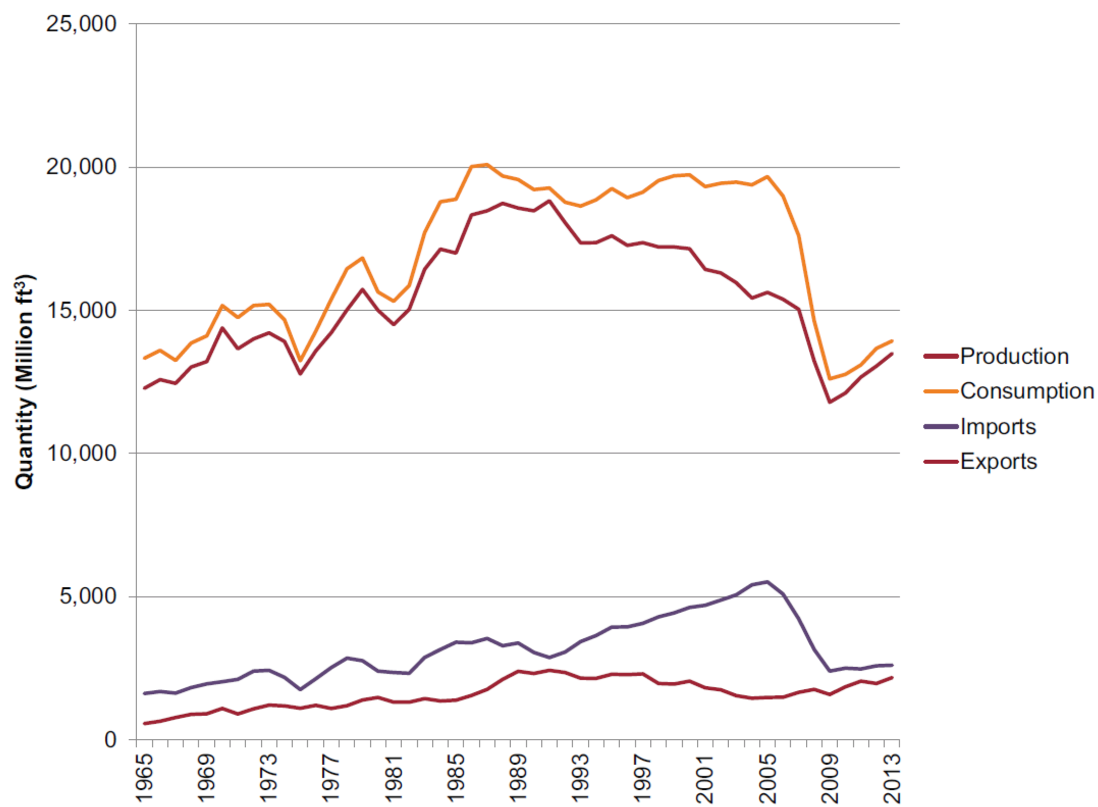


Figure 1. Production, consumption, imports, and exports of roundwood-equivalent timber products (million ft^3) in the United States, 1965–2013. (Source: Howard and Jones 2015.)