Carbon Uptake, Carbon Pools, and the Role of Forest Management in Sequestering Carbon

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Society of American Foresters
Growing better all the time

Contents

Forests are important

1. 30% of Earth surface is forest (4,100 M ha)

-- 80% above-ground carbon

	Area (%)	*Carbon* (%)
Tropics	50	37
Subtropics	10	
Temperate	10	14
Boreal	30	49

Includes Peats & Bogs

2. Change 1990-2000

Tropics deforestation = - 14.2 M ha/yr

Net World Loss = - 9.2 M ha/yr

FAO 2000
Percy et al., IUFRO 2003

Forest Carbon Issues -- Disturbance

1. Changes in Rate or Return Interval

Increased rate increases proportion of landscape in young age classes

2. Changes in Type

Deforestation, Harvesting, Wildfire, Insects/Disease, Wind, Drought, Ice, Conversion -- affect fate of C in different pools

3. Changes in Intensity

Affects amount of C release per unit area

Without human impact, and without climate change, world's forests in dynamic equilibrium

Forest Disturbance

World Deforestation .... - 9.2 M ha/yr = 18% annual GHG emissions

Wildfire ... 105 M t CO_2/yr (range 65.3 – 152.8) from 2000 – 2005 (EPA)
~40 tons CO_2/ac   Fate of dead trees – products or $CO_2 \nearrow$?

Insects ..... MPB in BC 14 M ha.   Beetle in pinyon = 1.4 M ha
MPB CO lodgepole 1.5 M ha ($12m emergency funding)

Wind .... Katrina = 2 M ha = 105 M t CO_2 = 1-yr uptake by US forests

Harvest .... 4 M ha/yr; 62% partial harvest. (3.8 M ha in 1907)
$^1/_3$ to $^1/_2$ C quickly released to atmosphere (Kurz & Conard 2005)

US Forests

Forestland: 303.2 M ha (33%) Timberland = 204 M ha

71,000 M t C -- 35% living biomass, 51% in soil, 13% dead material

155 M t C/yr sequestered. Av. rate (on timberlands) = 0.53 t C/ha/yr

Private forests = 63% of total US forest carbon

Equals ann. world deforest. loss

10-20% US emissions

0.74 t CO_2/ac/yr
Readily enhanced?

Carbon (t/ha)

hemlock-sitka spruce	354
chaparral	106
aspen-birch	309
loblolly-shortleaf pine	163

Heath, Smith, et al., 2003

Urban Forests

28 Mha = 3.5% of landbase

Average Tree Cover = 27%

Store 700 M t C at the rate of 22.8 M t C/yr

Definition of “forest”
= 10% cover

Nowak, 2002

1.13 t CO_2/ac/yr

Plus direct and indirect benefits of enhancing urban environment

Interestingly,

25 M dry tons /yr residue, only 25% recycled or used

→ 14.8 M tons of wood > annual FS harvest

Bratkovich et al., 2008

Carbon dynamics …

- Individual forests/stands <u>can be source or sink</u> for carbon depending on time since last disturbance
- After disturbance, forests are C source (release of C > uptake)
- As trees age and grow more slowly, dead OM accumulates, decomposition increases, C is released, and net uptake tends to zero.
- Unmanaged forest can become net source

Because US forests are so vast, small increases in sequestration rate and storage are very important

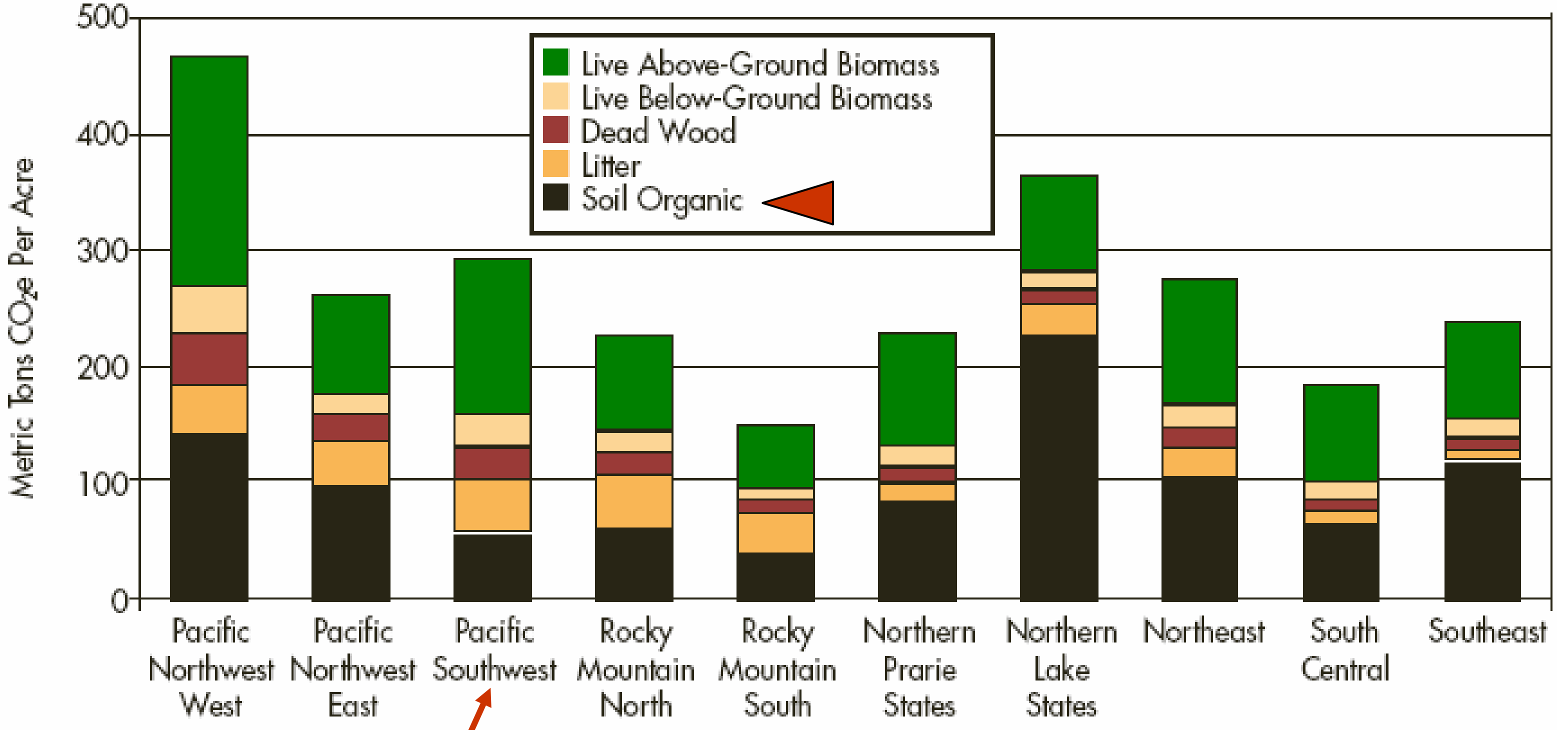
Forest Carbon Pools

1. Living tree – above ground / below ground
2. Standing dead tree
3. Down dead wood
4. Understory -- herbaceous
5. Forest floor -- litter
6. Soil

Need to account for carbon flux in each pool

FIGURE 6.

Forest Carbon Density by U.S. Region



Regions: PNWW (Western OR and WA); PNWE (Eastern OR and WA); PSW (CA); RMN (ID, MT); RMS (AZ, CO, NM, NV, UT, WY); NPS (IA, IL, IN, KS, MO, ND, NE, SD); NLS (MI, MN, WI); NE (CT, DE, MA, MD, ME, NH, NJ, NY, OH, PA, RI, VT, WV); SC (AL, AR, KY, LA, MS, OK, TN, TX); SE (FL, GA, NC, SC, VA).

Data from Smith and Heath 2006.

California

Ingerson, 2007

Soil Carbon

Within World’s Forests, 68% carbon in Soil

- Tropics ……… 50%
- Temperate …. 63%
- Boreal ………. 84% (Peat, Bogs, Permafrost)

(Kimble et al., 2003)

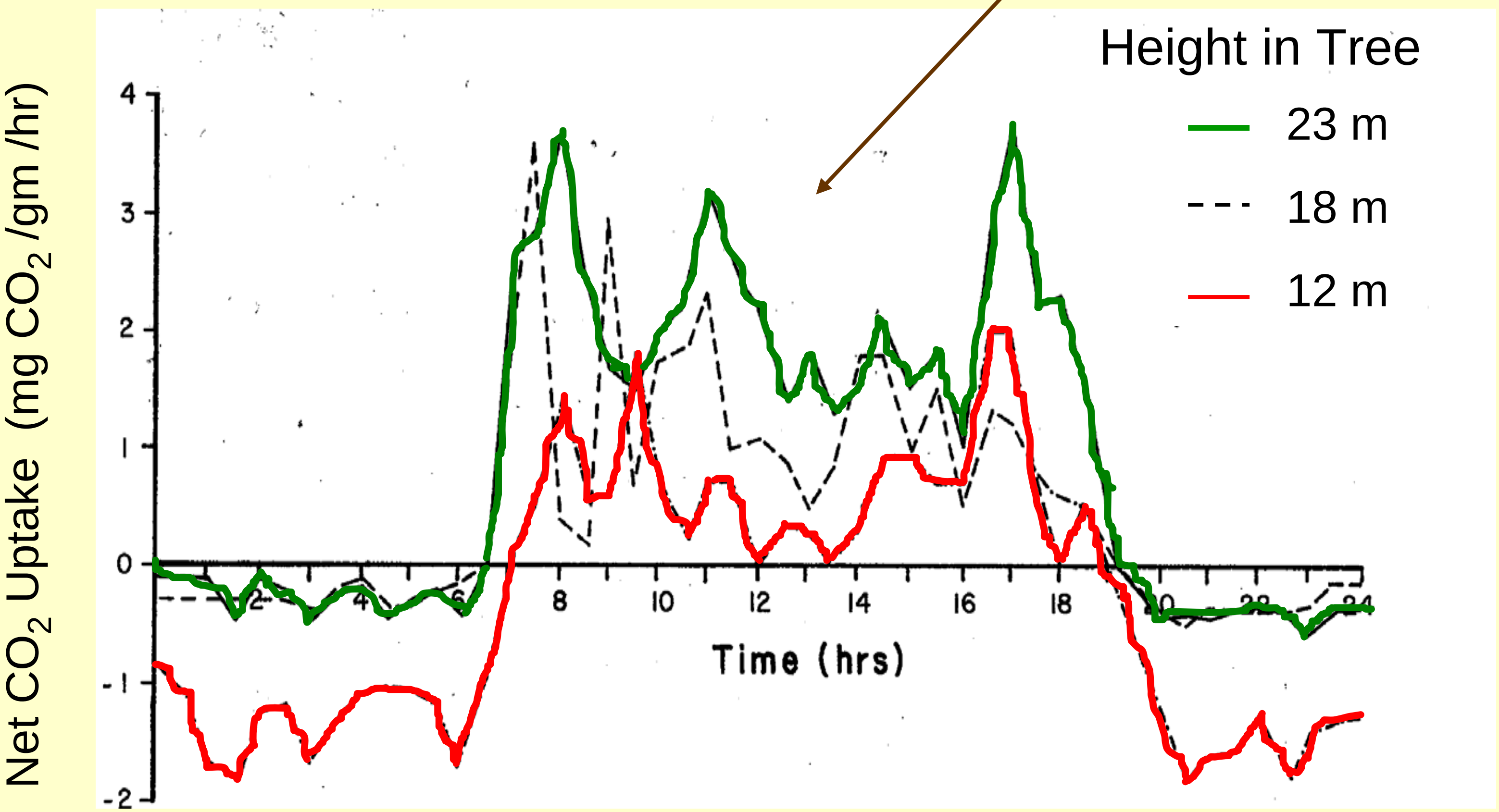
Sequestration rate = 105.9 (48.9 – 185.8) MtC/yr

(Heath, Kimble et al., 2003)

Immediately after harvest, soil C increases, declines below initial value for ~ decade, and then increases (Heath and Smith, 2000)

Importance of soils in forest management and silviculture

Net CO_2 Uptake by Trees



Cause of
"mid-day depression" ?

Helms 1968

Net Uptake of CO_2 by trees depends on:

Environmental Stress (temp., light, water, VPD, nutrients)

Genetics and species

Leaf Age

Crown position

Aspect

Season

CO_2 as fertilizer (European forest growth +20-40% since 1930s)

Cannell et al., 1998

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Carbon Uptake by Stands

Leaf Area

Rate and total amount dependent on species, site productivity, stocking

The more leaves ---

greater CO_2 uptake

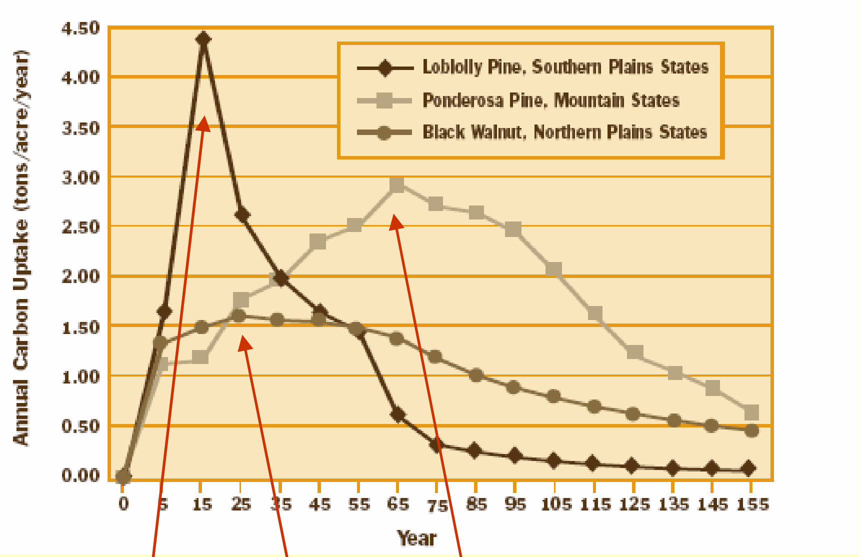
greater CO_2 loss due to respiration and decomposition

Tolerant species + high site → more leaf area, wood, and carbon

Intolerant species + high site → higher initial rates of wood and carbon prod.

Mixed-species stands intermediate: depending on proportion of tolerant/intol.

Rate of C Uptake



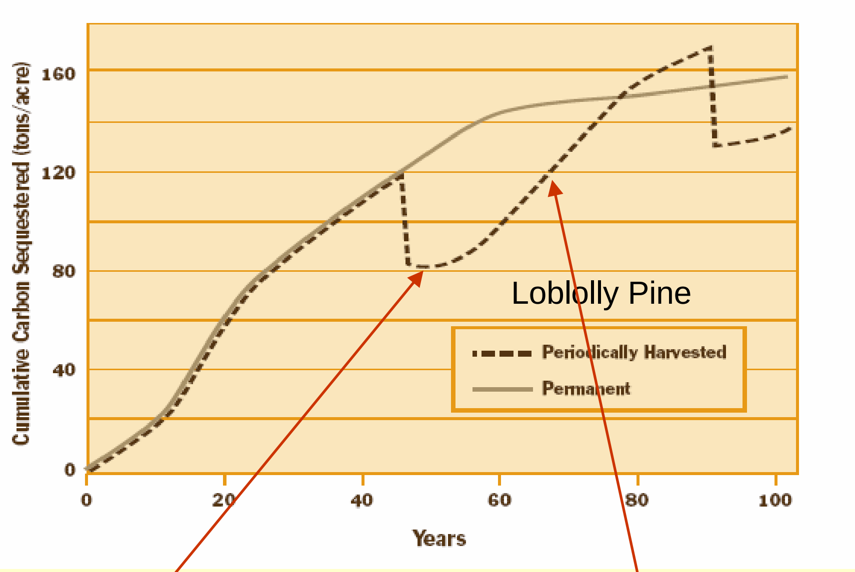
Loblolly
15 yr

Ponderosa
25 yr

Walnut
65 yr

Culmination

C Accumulation



Recovery period
Rebuilding leaf area

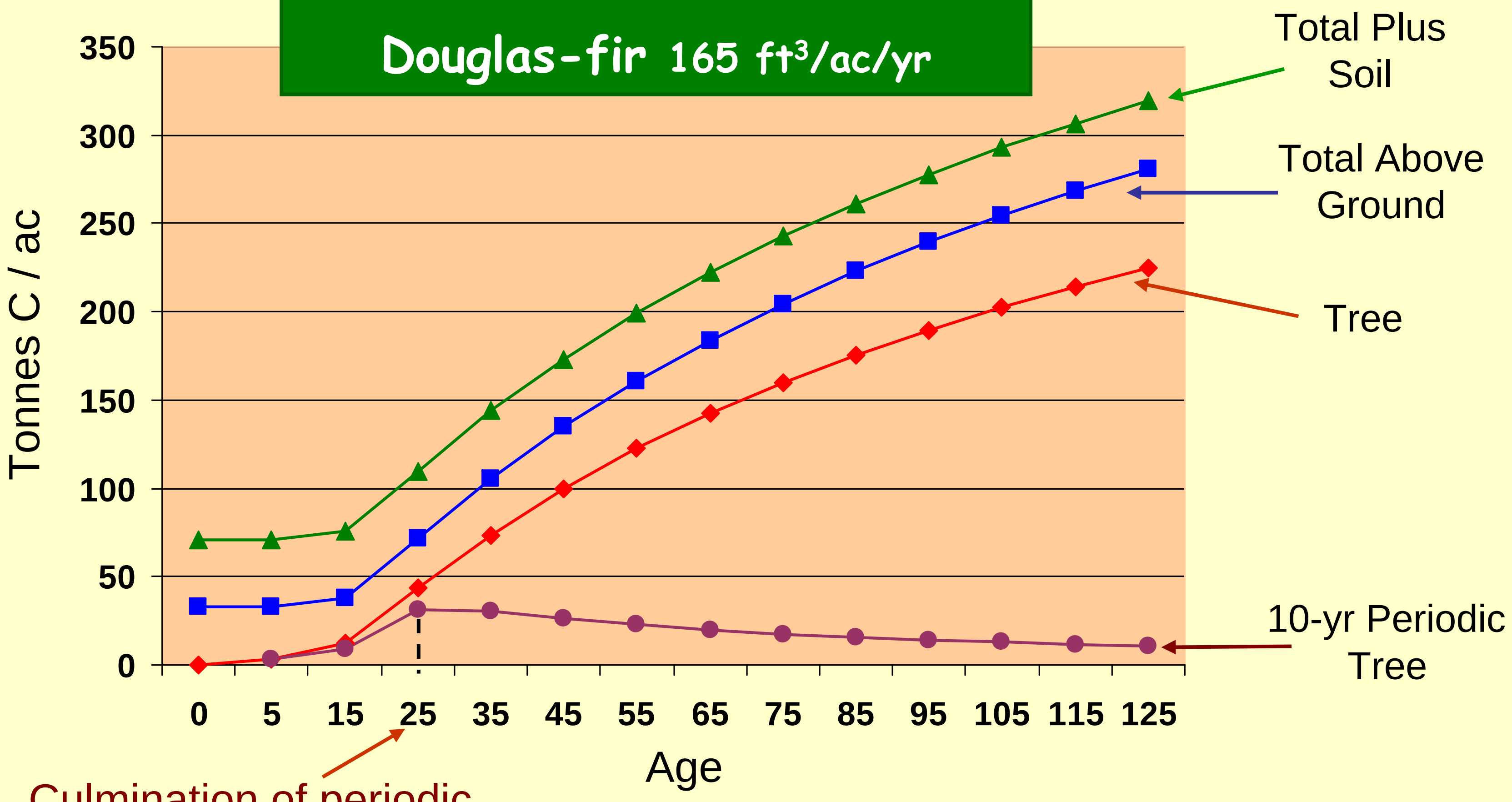
Restored high
uptake rate

From: Richards, Moulton, and Birdsey, 1993

In: Stavins and Richards. 2005. Pew Center on Global Climate Change.

Carbon Sequestration Rate and Accumulation

Douglas-fir 165 ft³/ac/yr



Culmination of periodic carbon sequestration rate

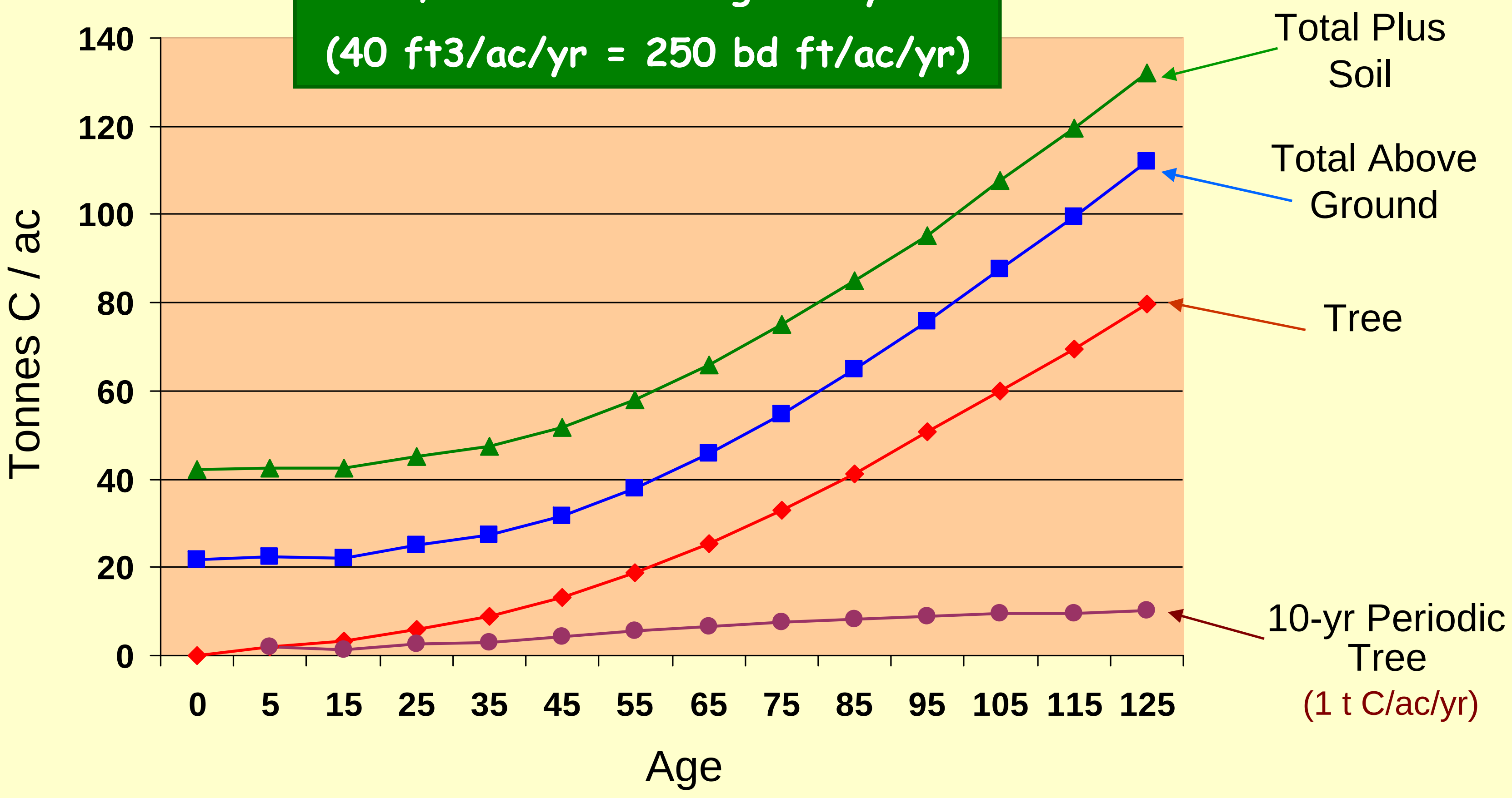
(3 t C/ac/yr)

Smith et al. 2006
Table A22

Mixed Conifer (California)

4,000 ft^3/ac at age 100yr

(40 ft3/ac/yr = 250 bd ft/ac/yr)



Smith et al. 2006
Table A27

Carbon Sequestration and Storage

Younger trees and stands have *higher* rates of carbon sequestration, but *lower* total storage

Older trees and stands have *lower* rates of carbon sequestration, but *higher* total storage

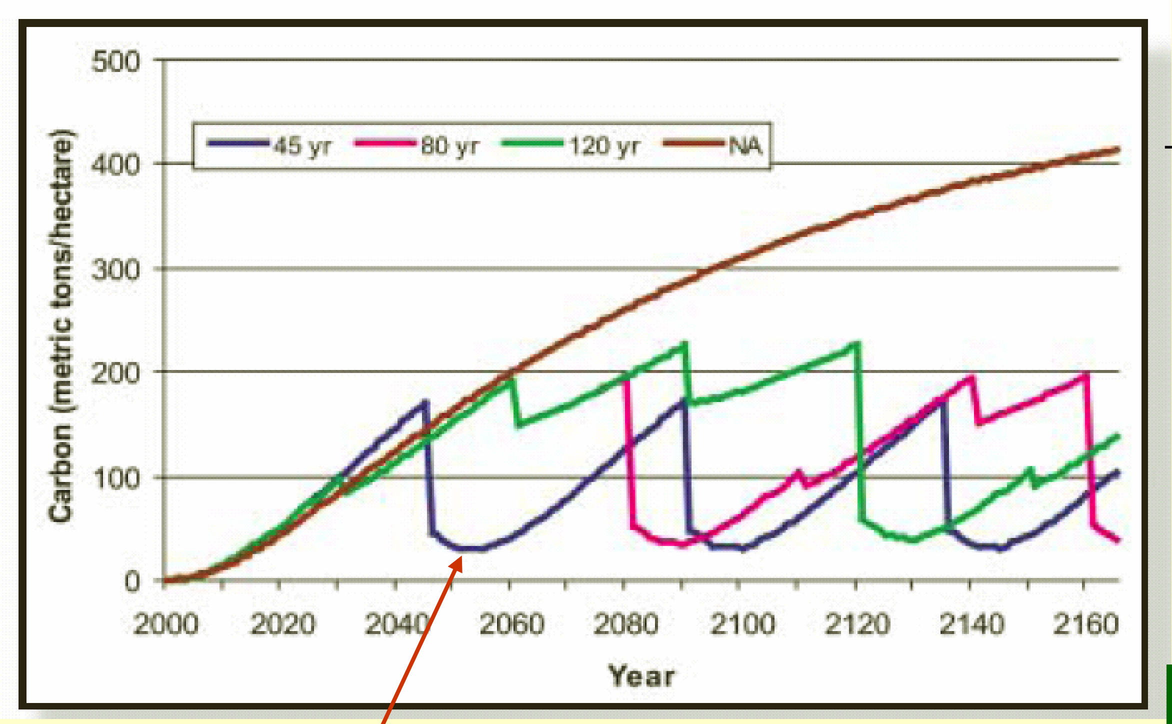
i.e., trade off – do you want to sequester or store?

(excluding issues of wildfire losses and wood products)

Forest Management and Carbon Sequestration

Carbon Storage in Unmanaged and Managed Stands

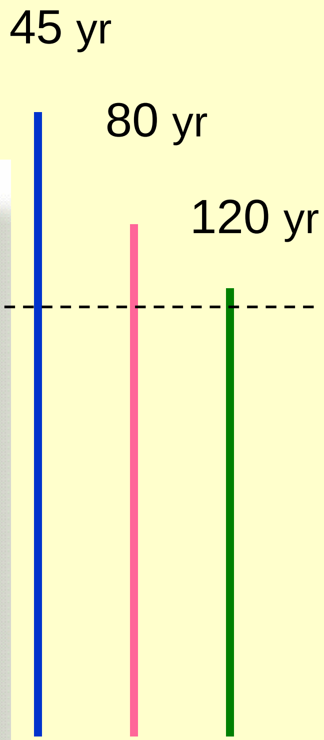
(even-aged)



Wilson, Oregon Conf. 2007

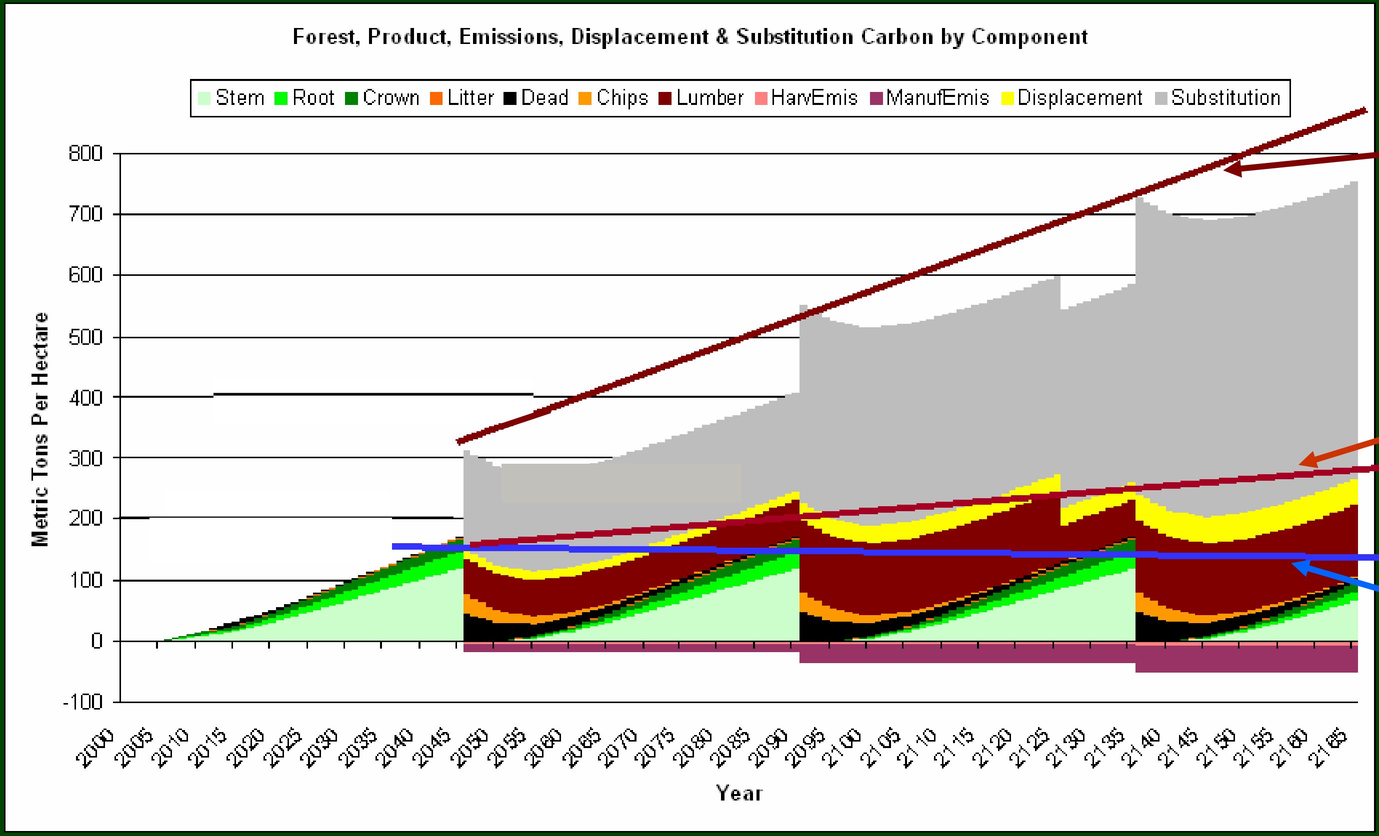
Regen. Period

Total carbon
by rotation



Excludes:
- C in wood products
- Use of wood vs. alt products

Forest, Product and Substitution Pools



With
Substitution
(Depends on type)

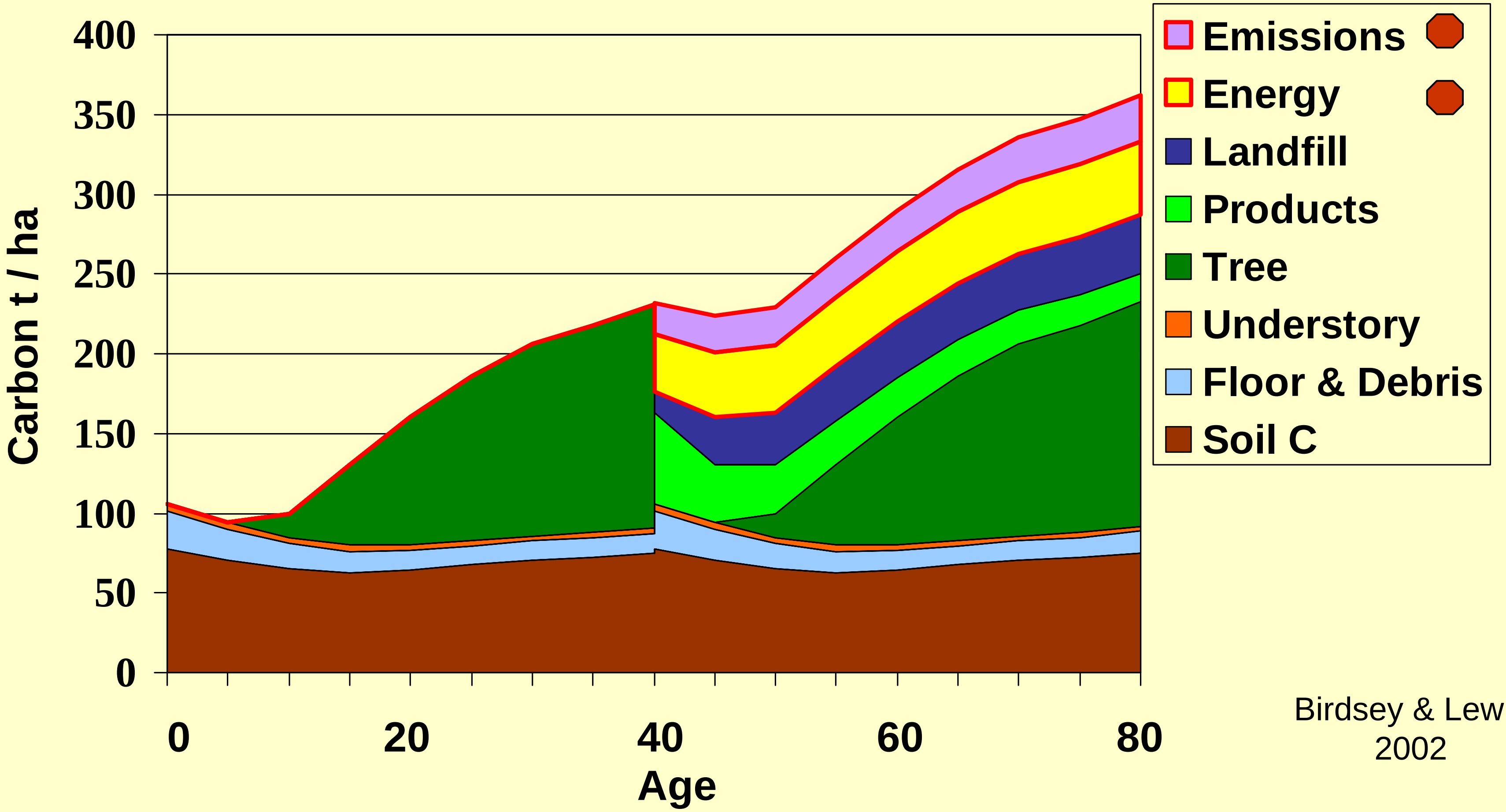
With
Products

Forest

Lippke, B. (CORRIM) 2007

Need to consider life-cycle assessments for alternative materials

Two Rotations of Southern Pine
Forest C and Disposition of C in Harvested Wood



Birdsey & Lewis
2002

⬣ Energy and emissions are releases of C to the atmosphere

Management benefits:

1. Sustained net uptake of C through photosynthesis and storage in healthy forests
2. Reduction of fossil fuel emissions through substitution for energy
3. Reduction of carbon releases due to mortality, decay, and wildfire
4. Carbon storage in long-lived products

Oneil, Lippke, and Mason 2007

Half-Life for Products by End Use

	years
Residential	100
Non-Residential	67
Furniture	30
Mobile Homes	12
Lumber & Panels	12
Railroad Ties	12
Pallets & Containers	6
Paper	2.6

DOE, 2006

Landfill ……. 100s of years ?

Three Key Strategies …

- Prevent conversion – Keep forest as forest
- Restore degraded or low-stocked forest
- Manage to enhance carbon uptake and storage on ground and in products

But …

Traditional management assumes climate stable

Should future management assume changed conditions?

Risk management (the higher the risk the more flexibility needed)

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Silviculture and Carbon Sequestration

Focus on:

- Production and maintenance of leaf area
- Stand density / stocking
- Avoid soil exposure and disturbance
- Priority on productive sites

1) Site Prep

“Minimum disturbance to provide temporary advantage”

Issues

Soil exposure and temperature

Oxidation of carbon (decomposition)

Effect on soil biota

Erosion

2) Regeneration

- Rapid crown closure, species choice
- Use seed/planting stock/species to accommodate predicted climate change i.e., "off-site"?
- Expectation for species to move north and upward in elevation -- +3.5 °C = ~200 miles north and ~2,000 ft elevation (Ryan, 2000)

3) Genetics, Tree Improvement, Biotech

Increased leaf area production and growth rate

Adaptation to changing climate?

Better, more competitive wood products

4) Weed / Shrub Control

- Role of understory in carbon uptake and competition vs. trees, habitat, soil cover, soil nutrition, aesthetics
- Shrub competition reduces tree growth, but same carbon could be sequestered by smaller trees + shrubs (total leaf area)
- Choice depends on relative values of wood and carbon, overall management goal, and if shrubs (above/below ground) can be inventoried

5) Fertilizer

- Increases leaf area, productivity (site quality)
- Energy/carbon cost of manufacture and application
- Volatilization, leakage

6) Thinning

- Maintains stand vigor (tree vs. stand growth)
- Temporarily lowers canopy cover (and stand C uptake)
- Light and frequent vs. heavy and infrequent
- Increases soil disturbance and exposure
- Reduces wildfire hazard
- Energy/carbon costs of treatment

7) Slash Disposal / Utilization

- Maintain nutrients vs. biomass energy
  (only important on lower site quality?)
- Lowers wildfire hazard (during decay period)
- Energy/carbon costs of treatment, transport, processing

8) Rotation / Cutting Cycle

Longer rotations ---

- Smaller proportion of time in regen. periods
- Larger tree sizes (cost of growing longer vs. value?)
- <u>Rate</u> of CO_2 uptake decreases over time
- <u>Amount</u> of carbon storage increases
- Will stands be thinned?
- Will decrease products and promote substitution?

9) Harvesting

- Interrupts canopy cover and sequestration
- Avoid soil exposure / disturbance / compaction
- Energy/carbon costs of equipment, transport
- Ensure rapid regeneration

10) Management System:

Even-aged
- Interruption of canopy and soil exposure
  - clearcutting, variable retention

Uneven-aged
- Continuous canopy, with gaps when regen. required
  - single tree and group selection

Tolerant vs. Intolerant species?

Pure or Mixed species?

Diversity over landscape?

Above all …

- Maintain forest health and vigor

- Reduce risk from:
    - insect/disease epidemics
    - wildfire

Conclusions

Forest management can play significant role:

- Mitigating emissions (forests as sink) -- sequestration
- Reducing emissions (forests as source) -- land use change, wildfire, insects
- Count products and substitutions
- More carbon sequestration in long run than unmanaged forest

But ...

Need Incentives

Management for carbon depends on …

- Protocols -- baseline, additionality, permanence, leakage
- Cost of inventorying, monitoring, verifying carbon flux
- Price of carbon (cap-and-trade) vs. wood, recreation, etc.

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It's an exciting time to be a forester !

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