# Vermont's Forests: Carbon and Climate Change

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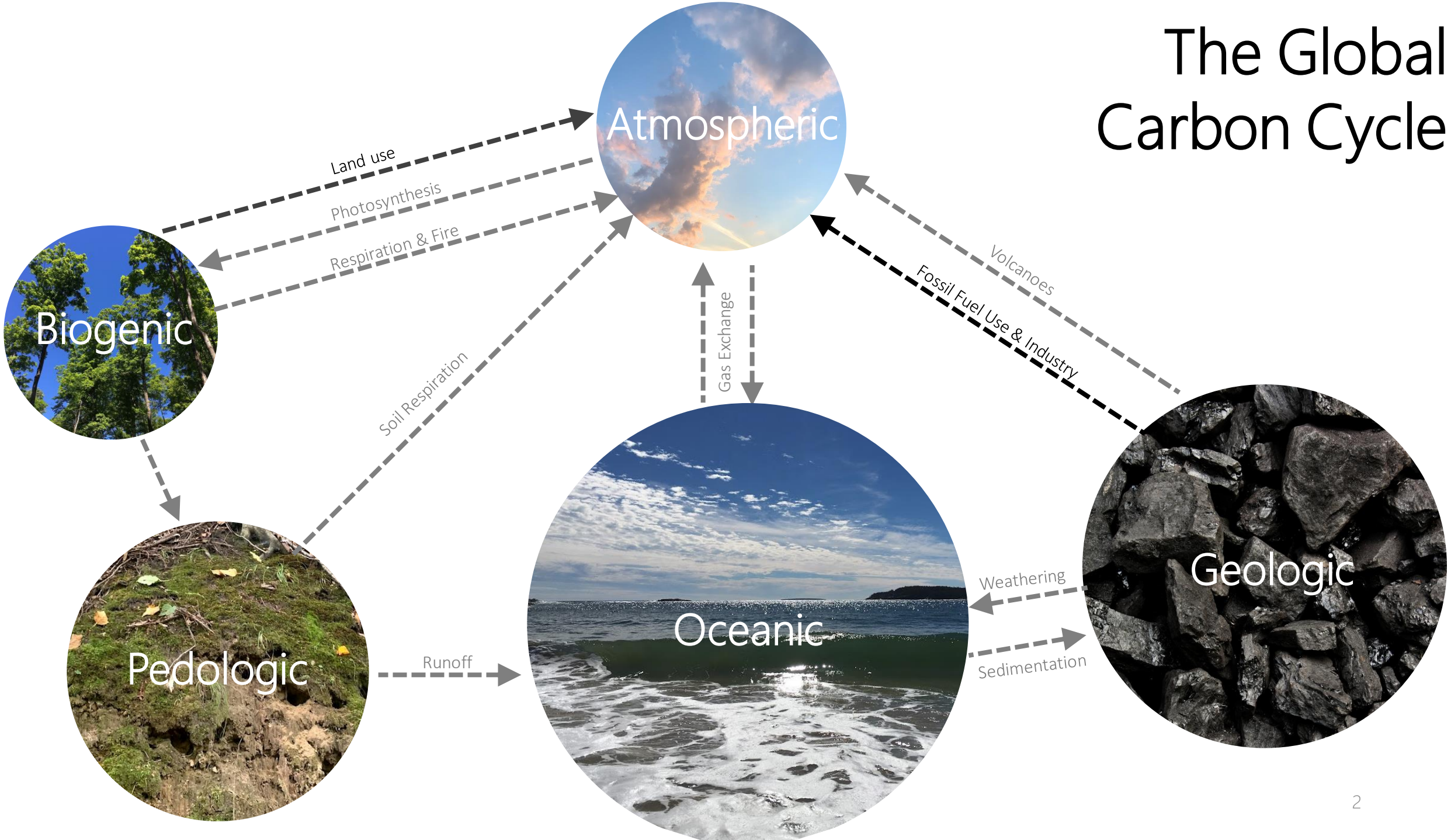
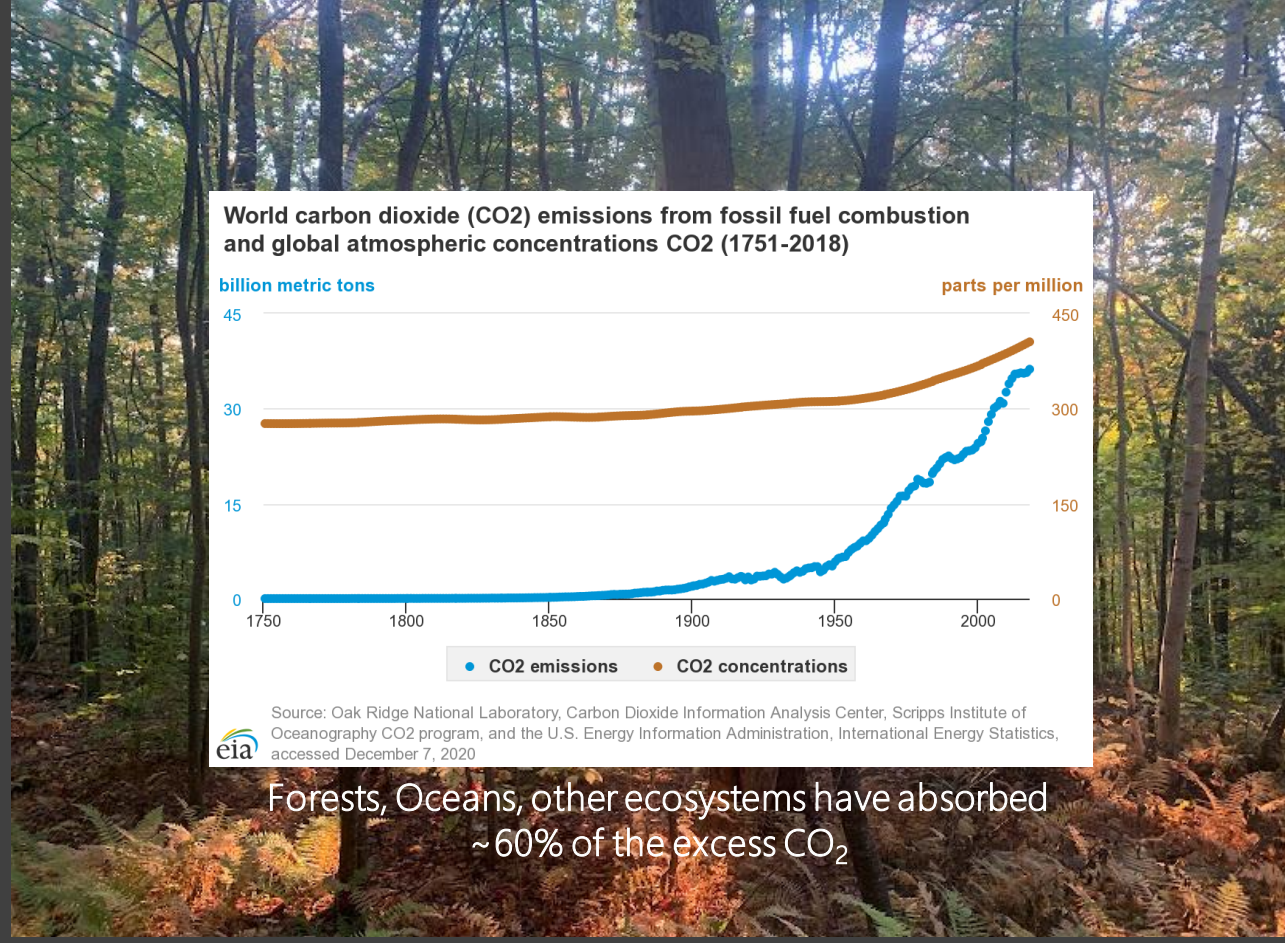
# The Global Carbon Cycle

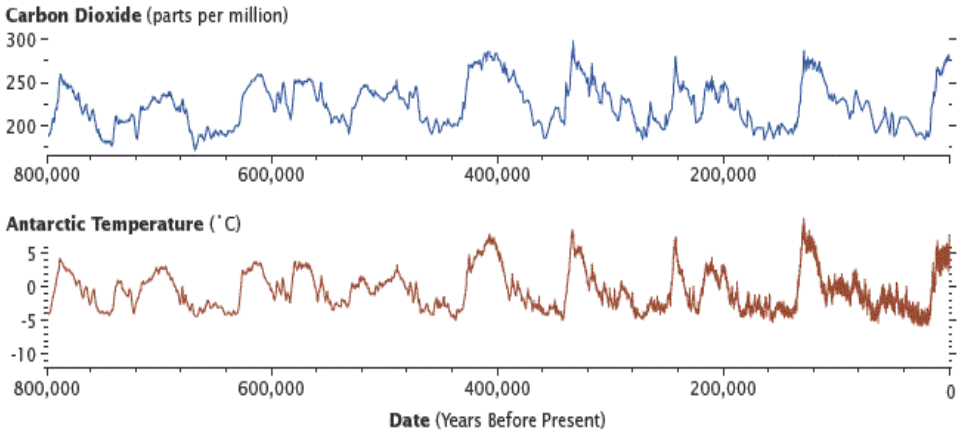


# Carbon released to the atmosphere has an affinity to form carbon dioxide ($CO_2$) which is a powerful greenhouse gas, trapping the Earth's energy



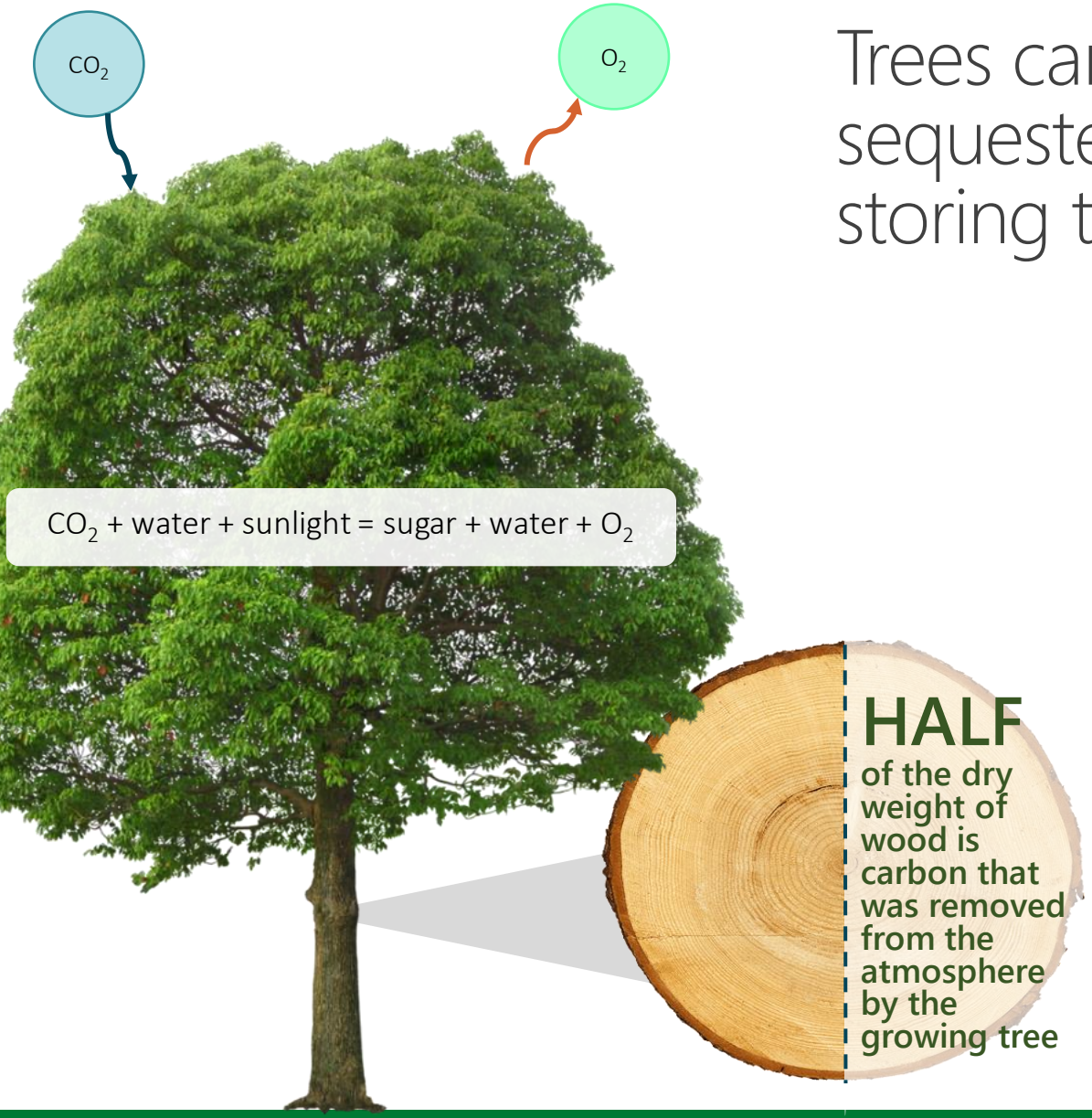

Forests, Oceans, other ecosystems have absorbed ~60% of the excess $CO_2$

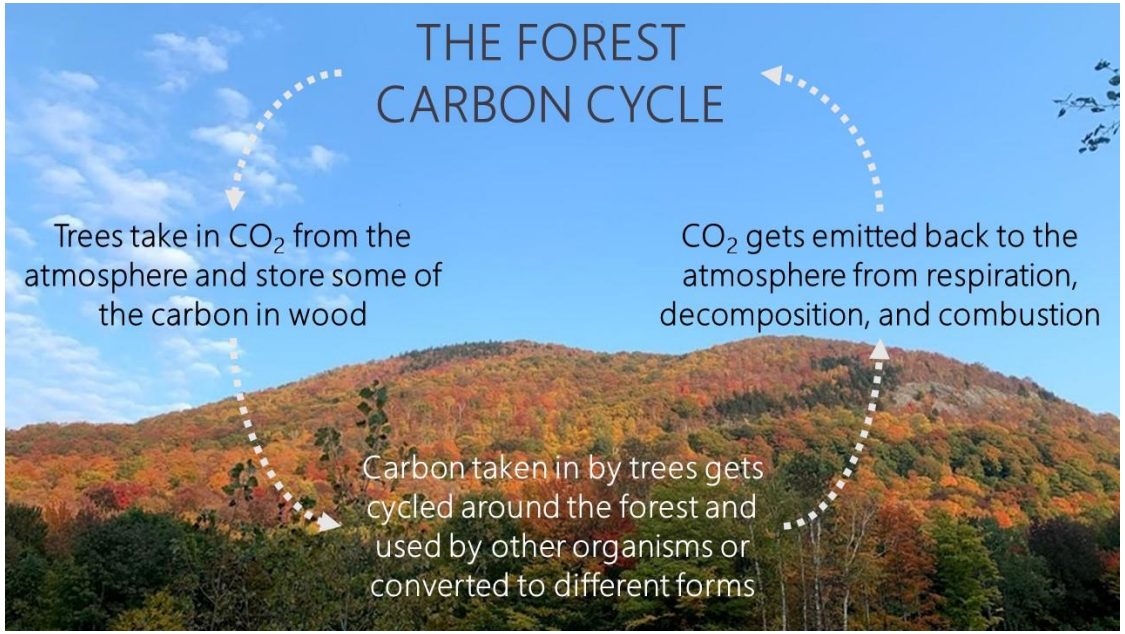
Atmospheric $CO_2$ concentrations are directly tied to global temperatures




Source: https://www.feedbackreigns.net/evidence/temperature-co2/

# Trees can help mitigate climate change by sequestering $CO_2$ from the atmosphere and storing the carbon in wood



# Quick Carbon Terminology Primer

**Carbon storage**

total the amount of carbon in an entity (tree, acre of forest, cord of wood)

**Carbon sequestration**

the process of taking $CO_2$ from the atmosphere and storing it

**Carbon emissions**

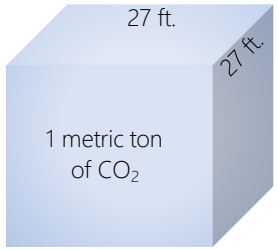
the opposite of sequestration ($CO_2$ release back to atmosphere)

**Carbon sequestration + carbon emissions = carbon flux**

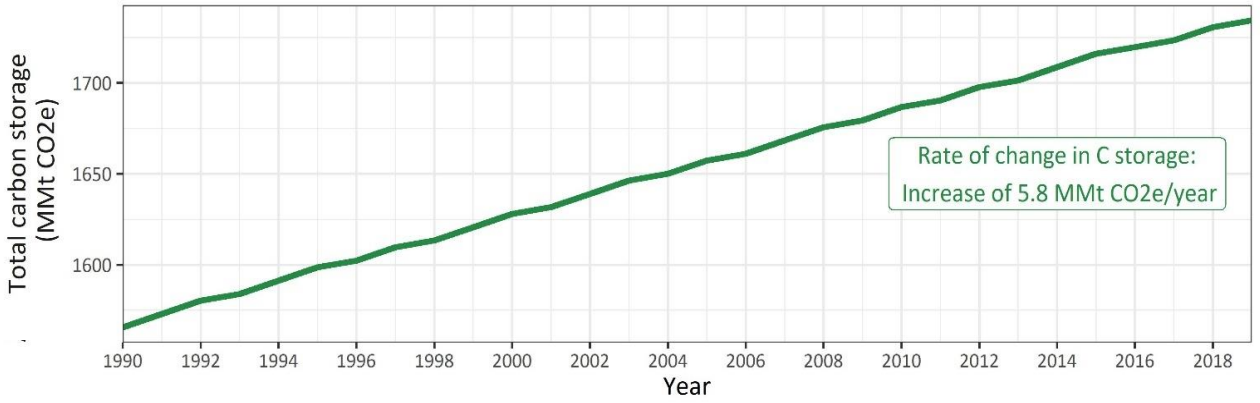
the change in carbon storage

- Negative values = sequestration
- Positive values = emissions

For easier comparisons, we convert carbon and other greenhouse gases to the same units = **carbon dioxide equivalent ($CO_2e$)**

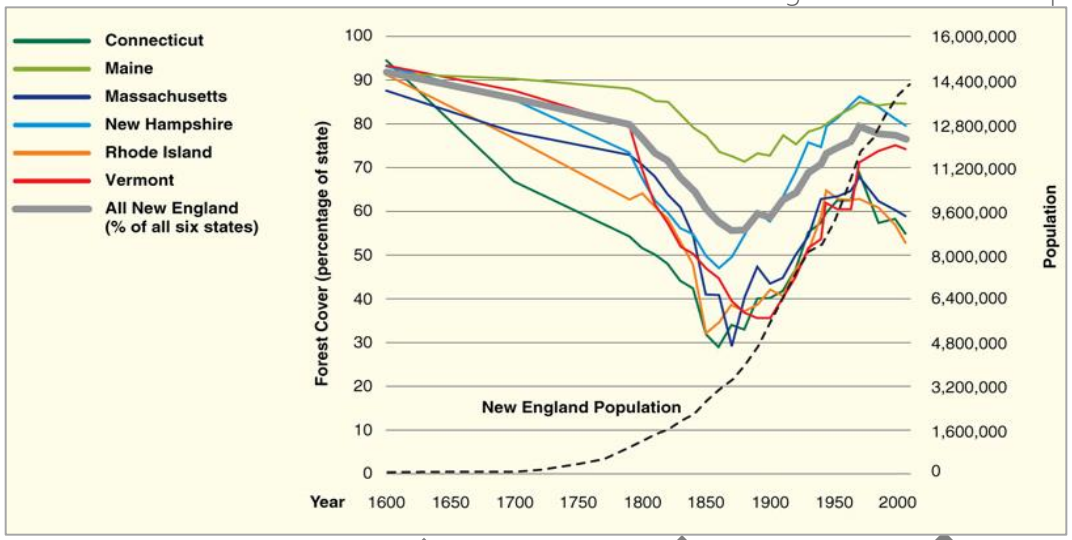



# VT's 4.5 M acres of forest are a net carbon sink




Forest loss = net carbon emissions

Forest gain = net carbon sequestration




Source: Wildlands and Woodlands.org

Forest carbon stock 9167 MMt $CO_2e$

Pre-industrial

Forest carbon stock 9060 MMt $CO_2e$ (-107)

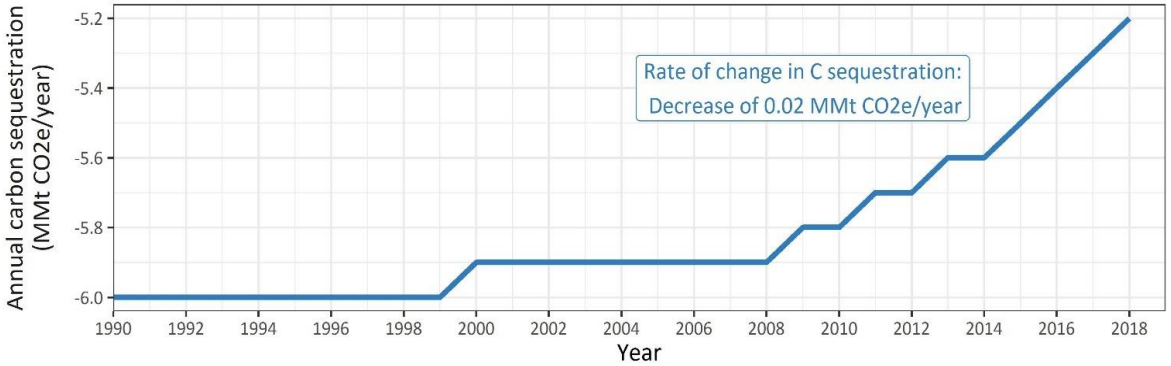
1850

Forest carbon stock 9100 MMt $CO_2e$ (-67)

2017

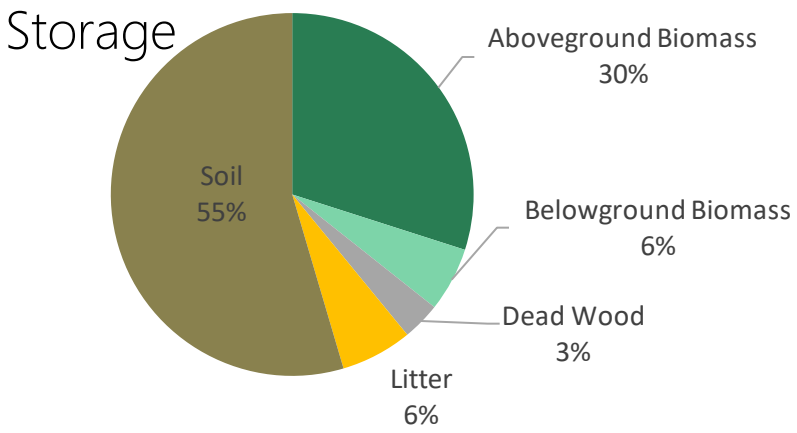
Still have not fully recovered to pre-Industrial levels

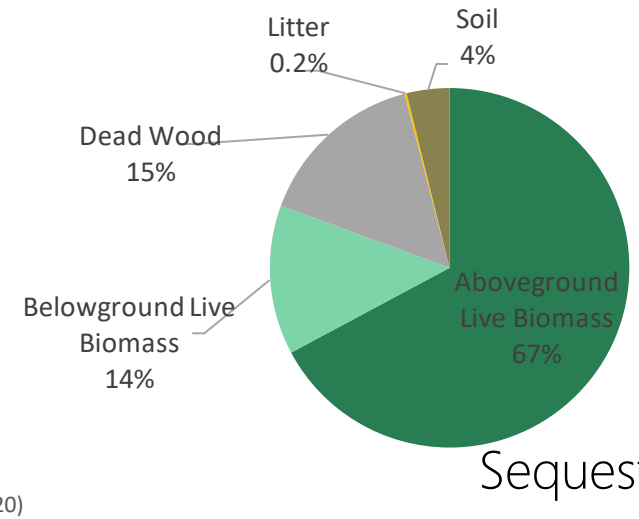
## But the rate of sequestration is declining



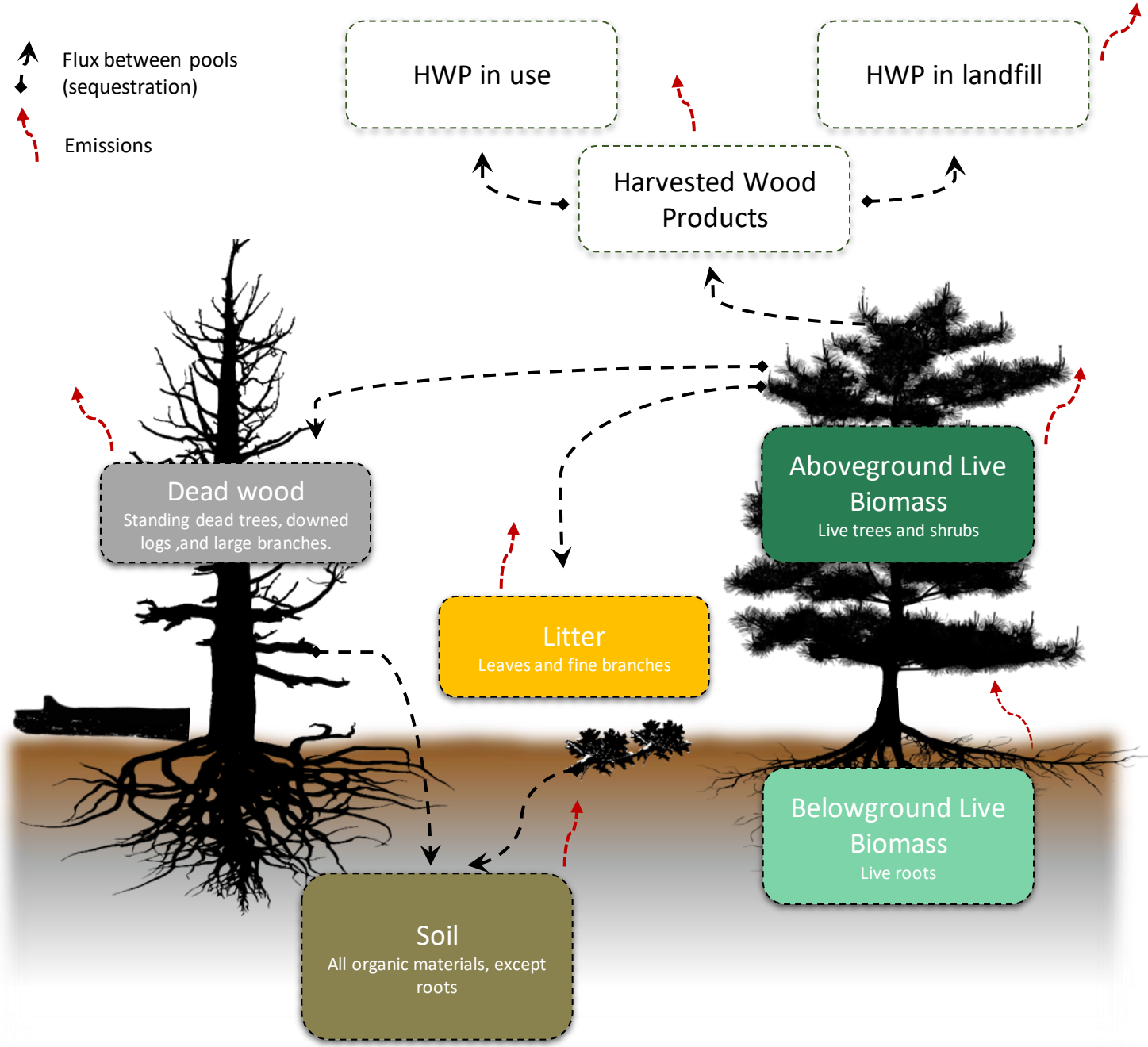

Data source: Domke et al. 2020

# Forest carbon pools




Data source: Domke et al. (2020)



# Mitigation potential of forests depends on the balance between uptake and release

**Carbon sequestration**

(photosynthesis, storage in forest pools)

**Carbon emissions**

(respiration, decomposition, combustion)

CLIMATE FACTORS
- Temperature and precipitation
- Length of growing season

SITE FACTORS
- Nutrient, light, water
- Soil
- Disturbances, insects/disease
- Tree density, size

TREE FACTORS
- Species, age
- Stress

# Not all forest stands are carbon sinks

<u>Carbon sink</u>

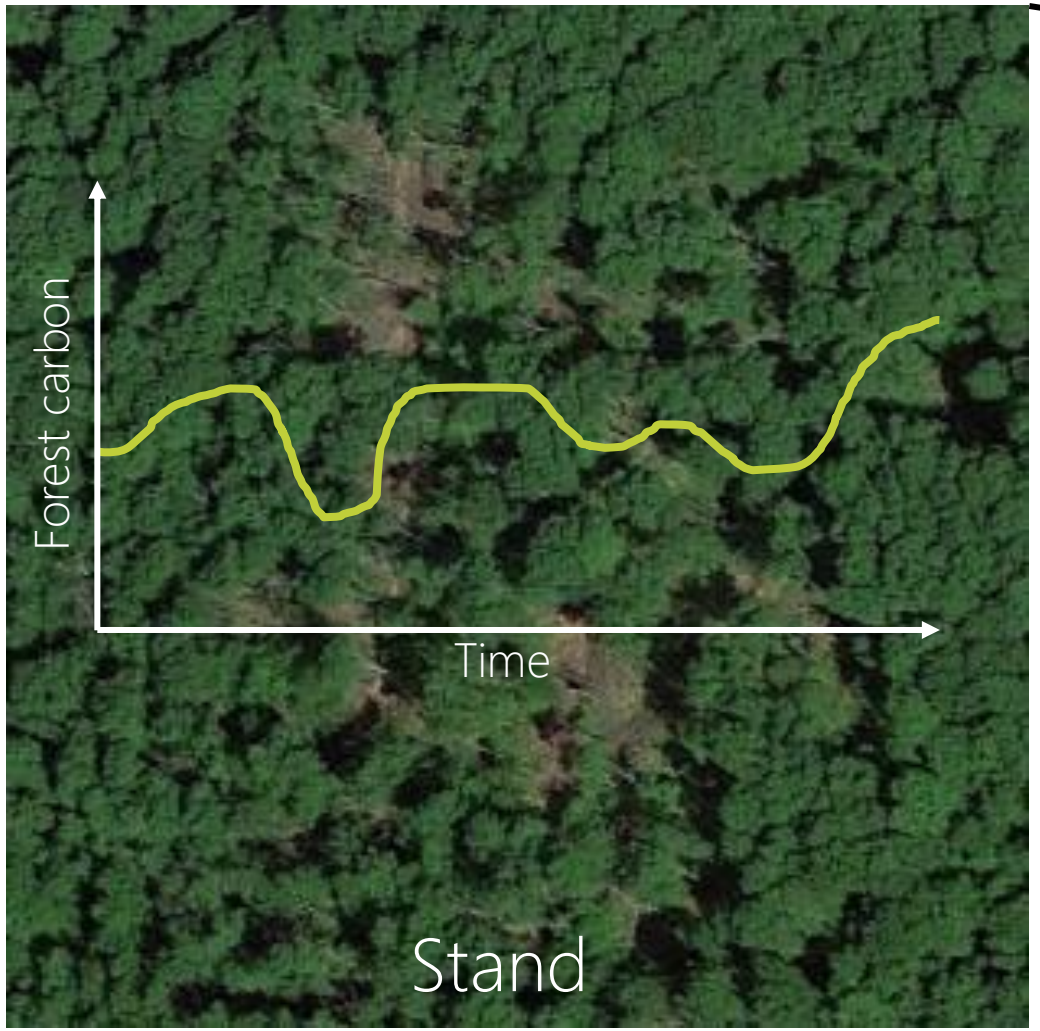
Sequestration > Emissions

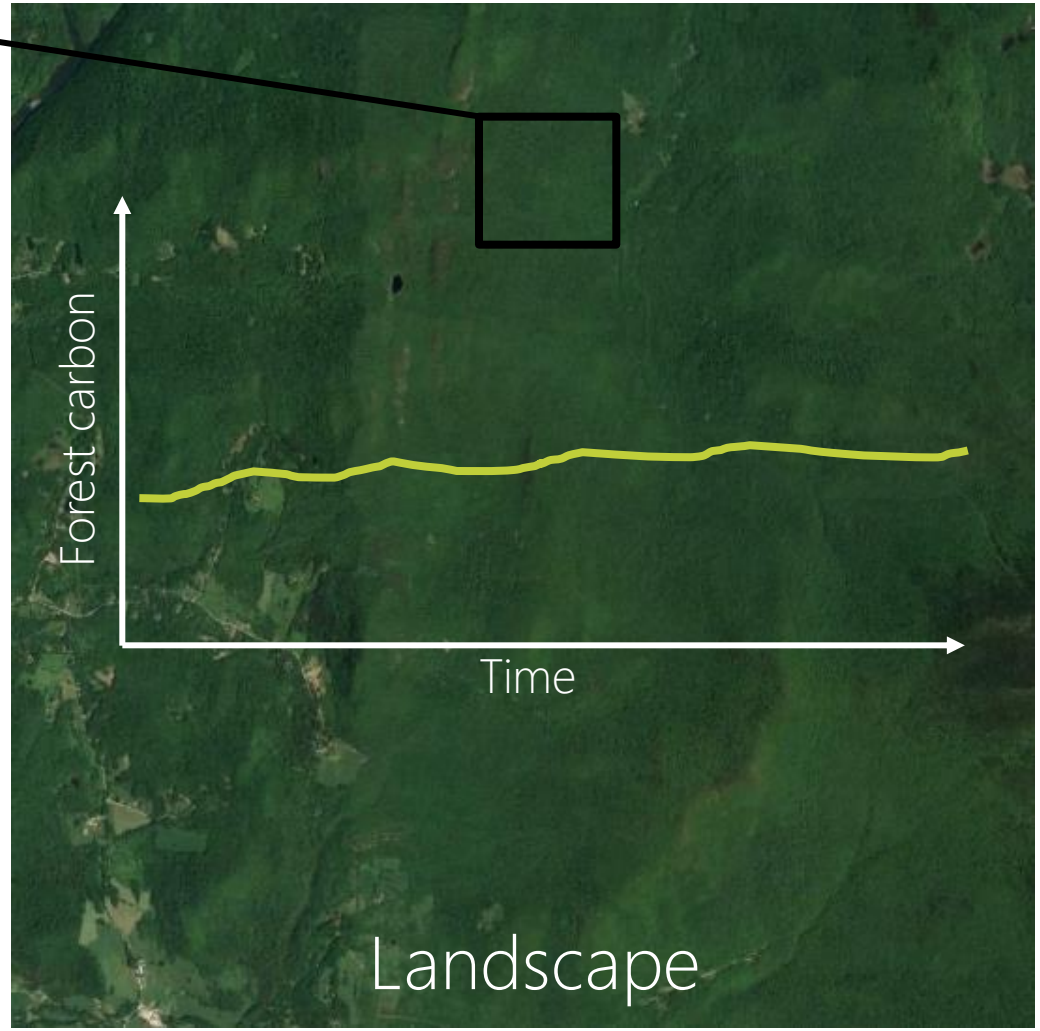
<u>Carbon source</u>

Sequestration < Emissions

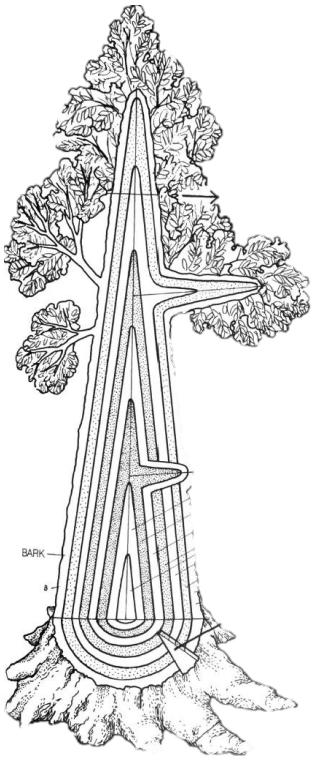
Image: Naveen Nkadalaveni

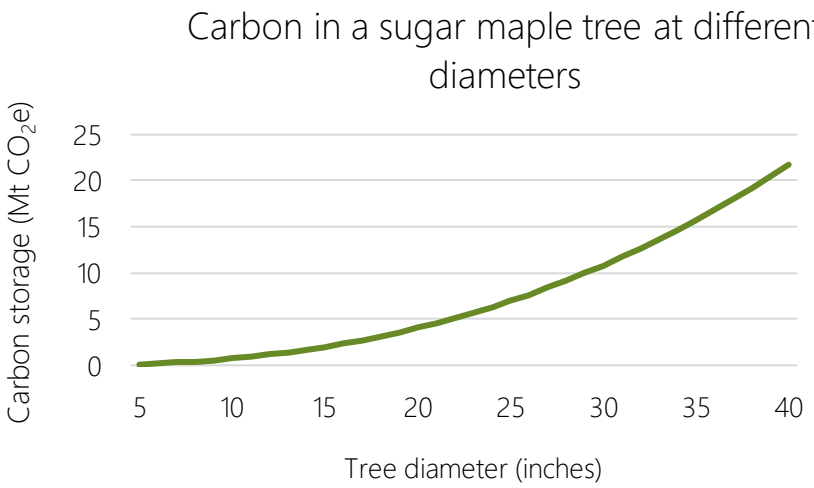
# Forest carbon dynamics depend on the spatial and temporal scale



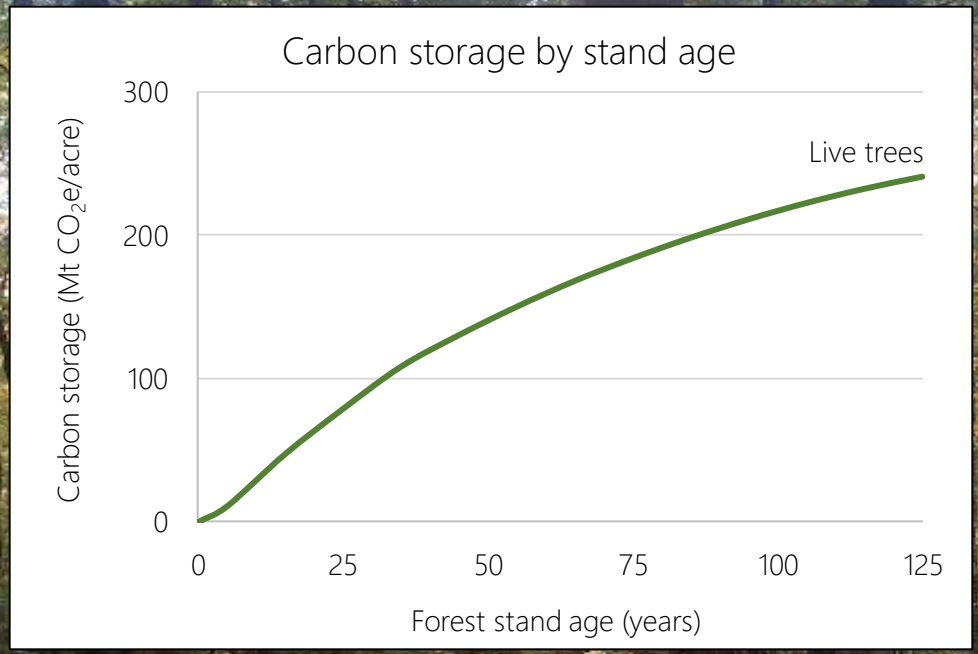



# Carbon in a tree vs. forest



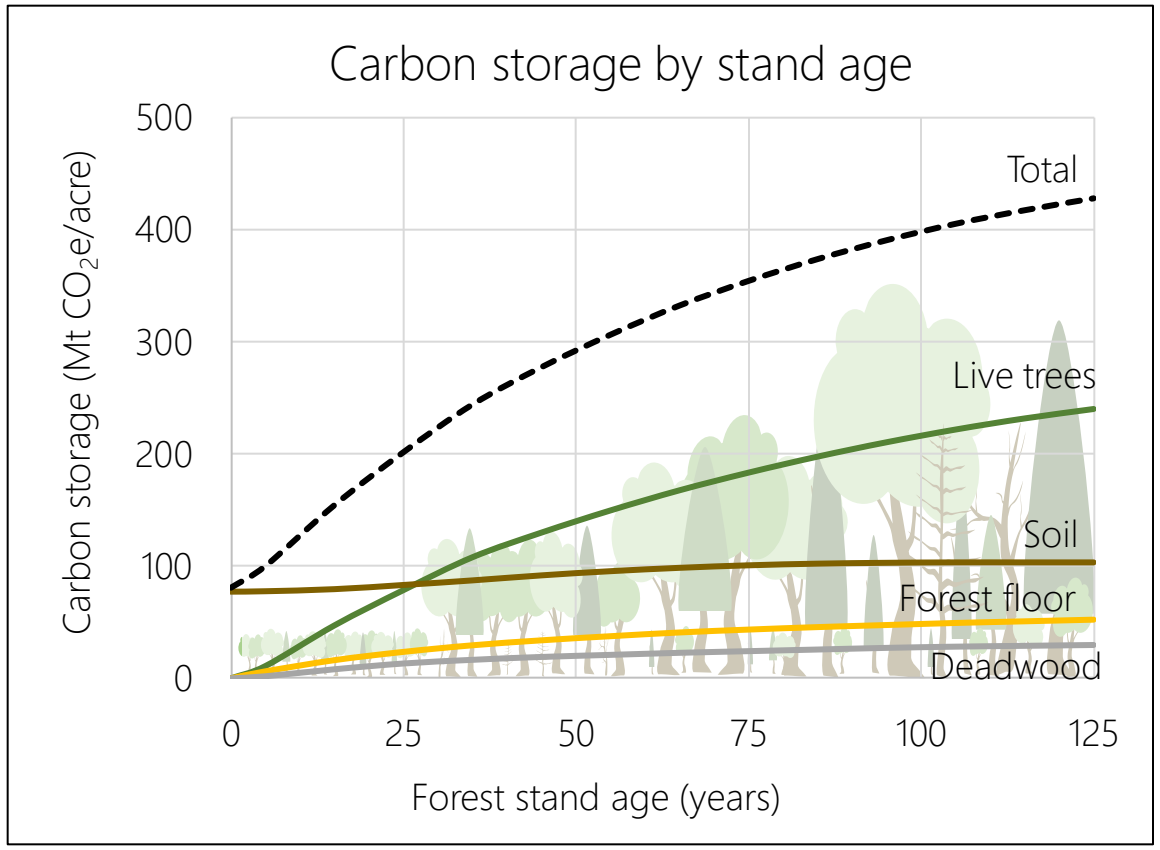



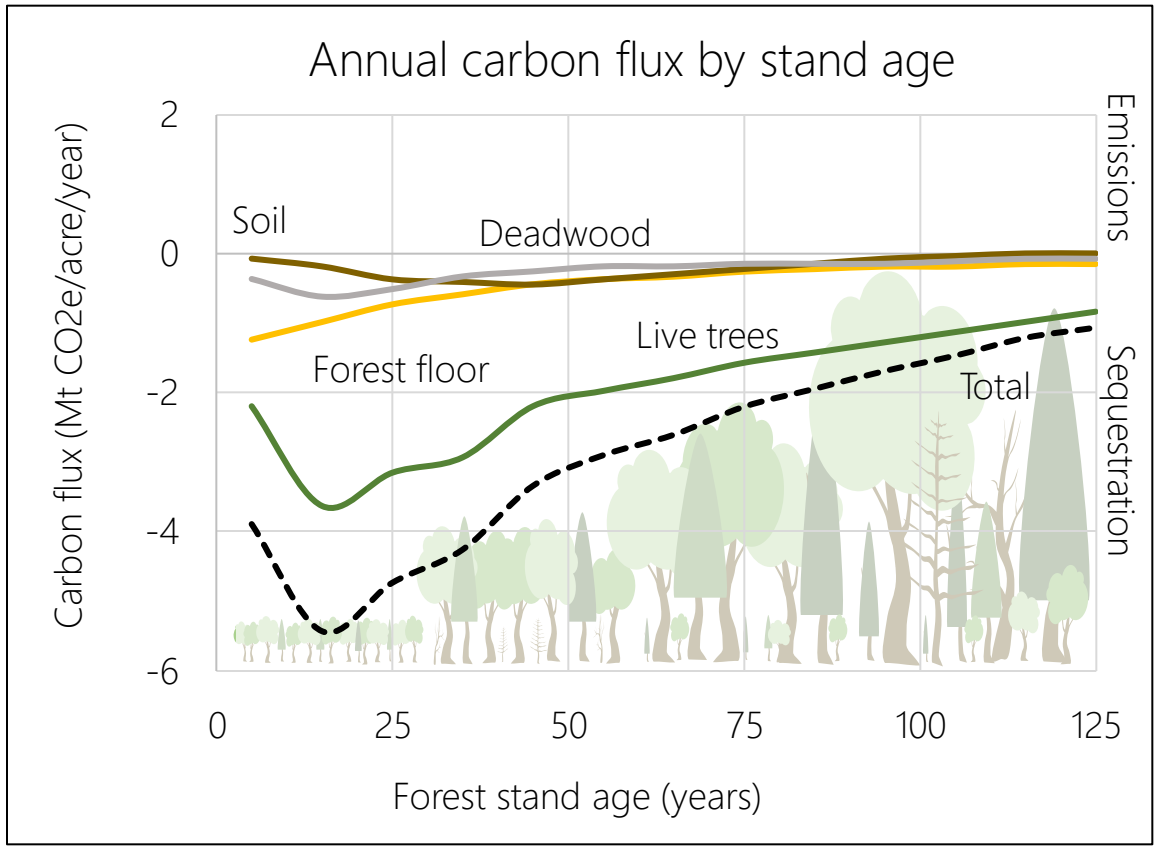




# Carbon storage and carbon sequestration peak at different life stages

Take home message: stand age diversity across the landscape is key




Data source: Smith et al. 2006 - carbon stocks and fluxes following afforestation for maple-beech-birch forest

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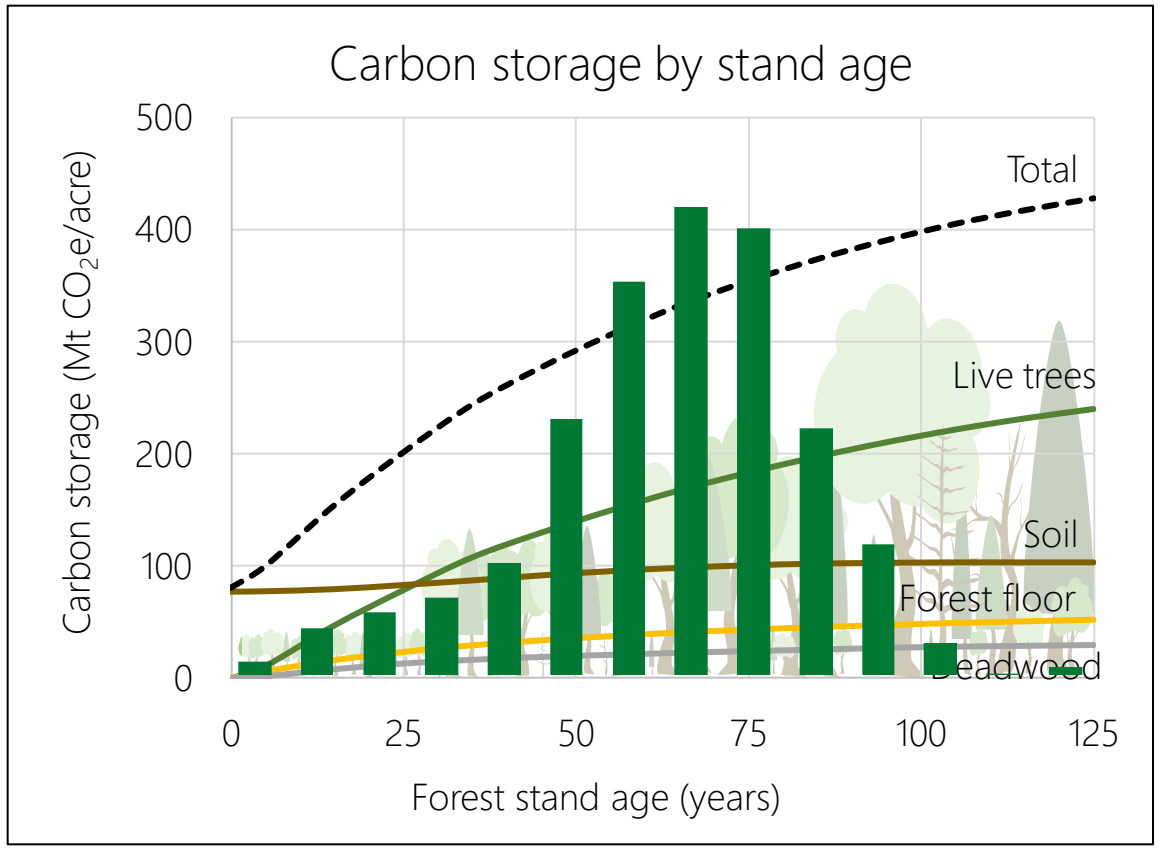
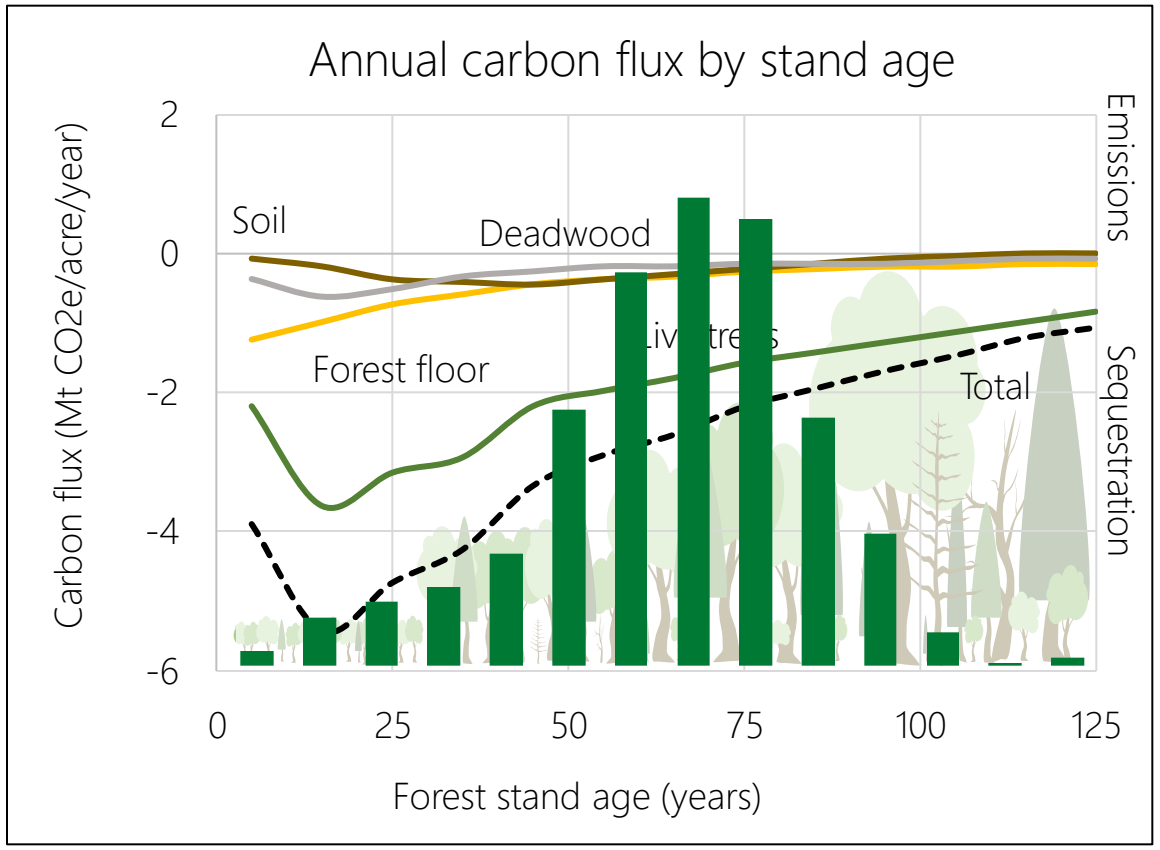
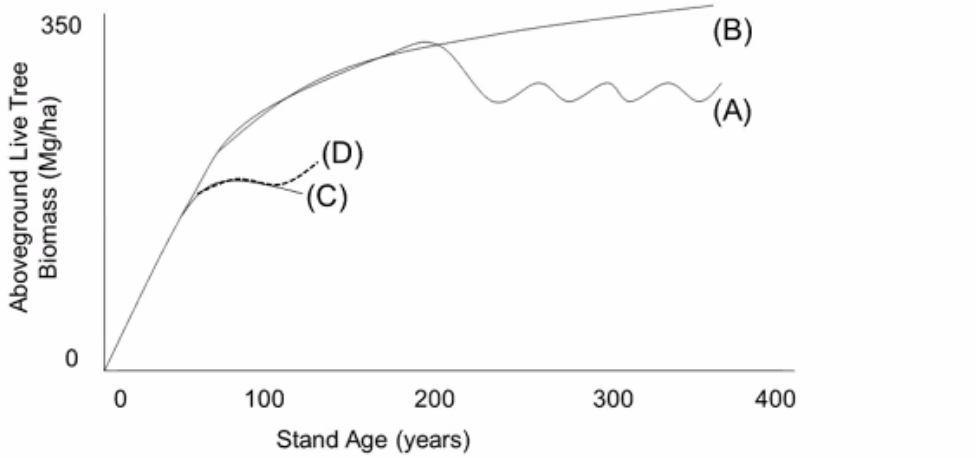



Data source: Smith et al. 2006 - carbon stocks and fluxes following afforestation for maple-beech-birch forest

# While older forests on average store more carbon, there are many trajectories that a forest can follow



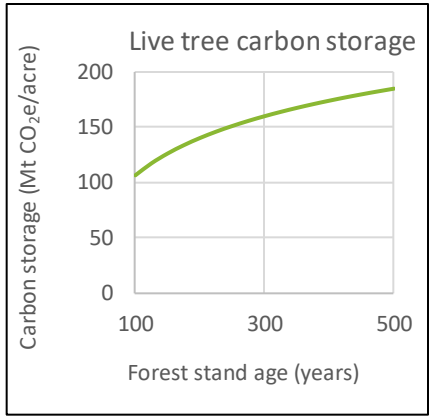

From Keeton 2018. In: Barton and Keeton, Island Press

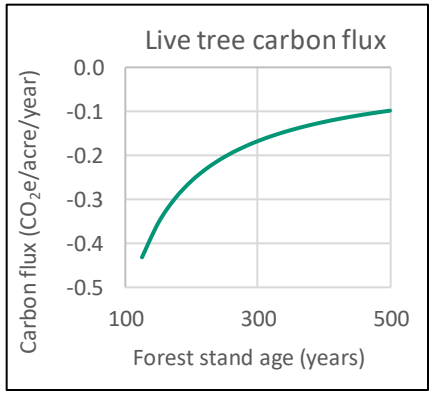
Depends on

- Tree species
- Site quality
- Past land use
- Disturbance events
- Stressors
- Pests and pathogens
- Climate

Carbon Data from Old Forests in New England

Data source: Keeton et al. 2011



# How does forest management affect forest carbon?

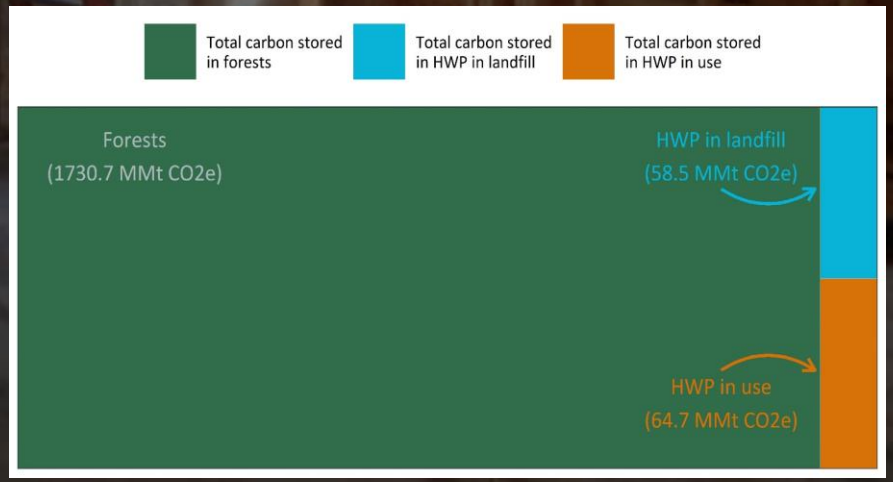
- Harvests reduce forest carbon stocks of the stand because there is a removal of some amount of carbon (wood)
- Soils are typically not impacted much except by equipment
- an cycle carbon to other pools, may result in positive fluxes due to high amounts of deadwood and decay
- Can result in more rapid carbon sequestration as new trees grow up
- High variability depending on site, silvicultural systems, equipment, retention, time of year
- When considering impacts of management, we must consider LEAKAGE

# Harvested wood products store carbon for as long as they are in use

**Carbon storage** for as long as product is in use, and when it is no longer in use and is in a landfill slowly decomposing.

Can provide additional $CO_2$ reduction benefits by acting as a **substitute** for high GHG products (steel, concrete, plastics, fossil fuels)

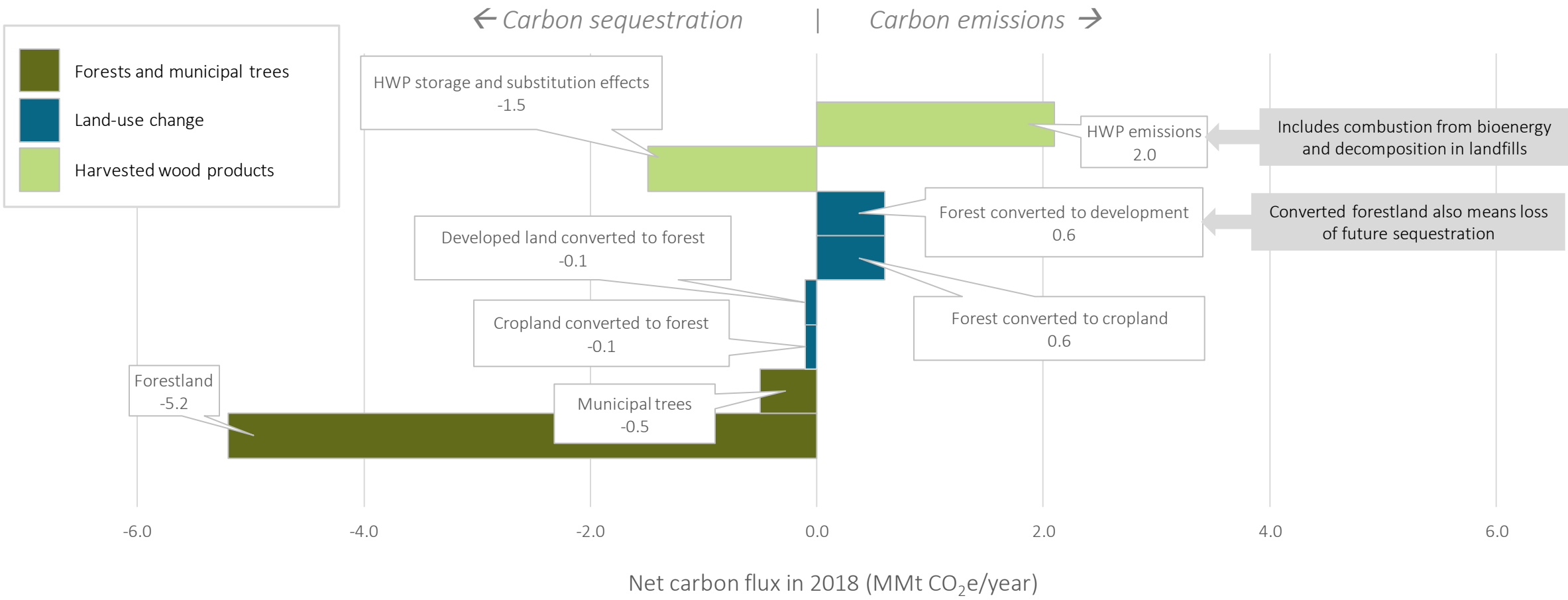
HWP contribute 7% to total carbon storage of the VT forest sector




Data source: Domke et al. (2020) and Dugan et al. (2021)

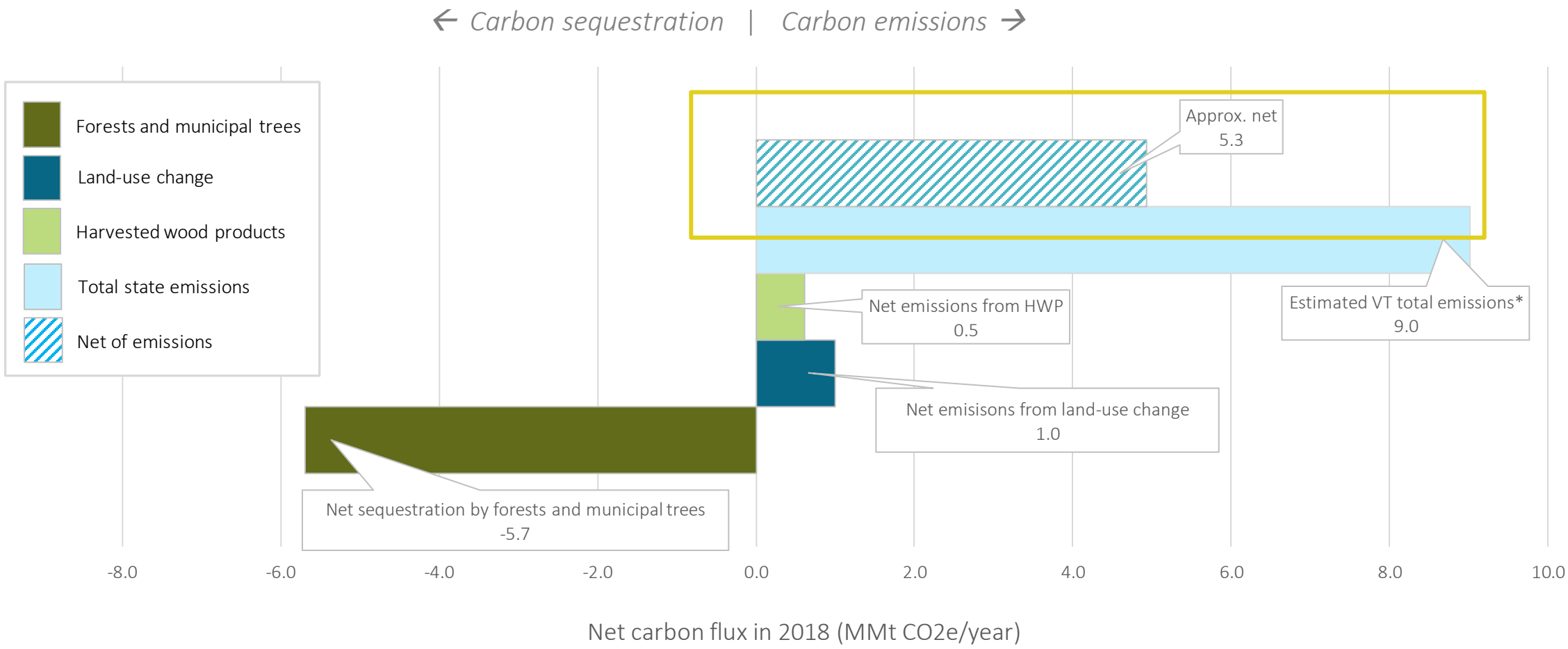
# Across the VT forest sector, there are carbon sinks and sources

Note: estimating carbon is difficult and these values are approximate



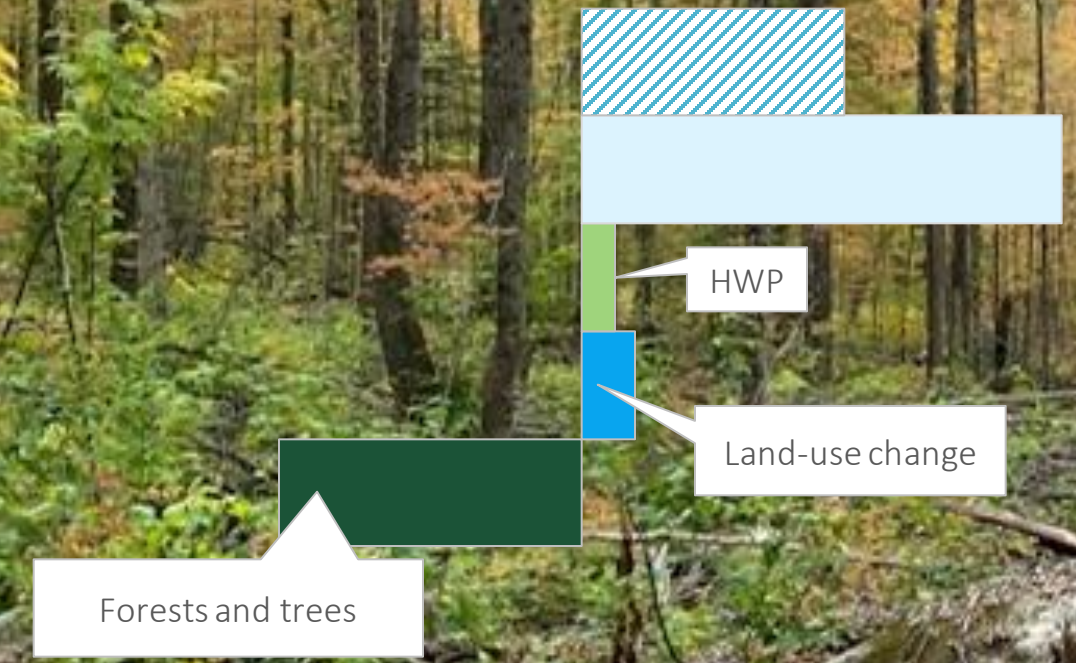

Kosiba AM. 2021. Vermont Forest Carbon Inventory. Data sources: Domke et al. (2020) forest and tree sequestration and land use change estimates; Dugan et al. (2020) HWP emissions and substitution estimates

# When we combine the sinks and sources estimated for 2018, the forest sector took in ~42% of state annual emissions



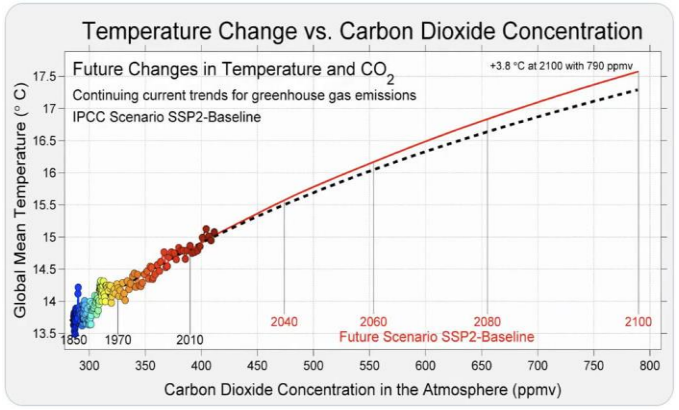

**Kosiba AM. 2021. Vermont Forest Carbon Inventory.** Note that these forest sector values are not included in the Vermont GHG Inventory. Data source for state emissions: VT ANR GHG Inventory (2020), estimate for 2018

# Opportunities to maintain and increase the mitigation potential of the forest sector




- Maintain or increase carbon sequestration of forests through good stewardship and ecological silviculture
- Maintain or increase carbon sequestration of municipal trees through good stewardship and additional tree planting
- Reduce carbon emissions from land-use conversion and maintain the forest carbon potential
- Decrease net HWP emissions by increasing use of wood as substitutes, durable wood products

# Climate change itself poses a risk to the ability of forests to sequester and store carbon, and to keep it stored for long periods of time




Source: Berkeley Earth

- Increased mortality?
- Lower growth rates?
- More stressors?
- More disturbances?
- Faster decomposition rates?


## ***Climate-resilient forests are the best path to ensure a long-term climate mitigation effect***

"Resilience" means the capacity of forests to withstand and recover from climatic events, trends, and disruptions.

"Adaptation" means reducing the vulnerability and advancing resilience through enhancements to, or avoiding degradation of, forests.
(from the VT Global Warming Solutions Act)

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