



USFWS: Brent Lawrence. "Diablo Lake in the Northern Cascades" Flickr, 3 November 2023, <https://www.flickr.com/photos/52133016@N00/33145062751/>.

# Forest Carbon Modeling Component

**Cedar Morton, Don Robinson, Eric Neilson, Frank Poulsen, Alex Tekatch, Clint Alexander**

Friday, February 14, 2024





# Outline

- Our team (10min)
- The two carbon modeling options (15min)
- Q&A (35min)



# ESSA Technologies (ESSA)

“ESSA brings together **people, science** and analytical **tools** to sustain **healthy ecosystems** and **human communities**. We envision a world where creativity, a focus on learning, and systems-thinking are the foundation of solutions to environmental challenges.”



**Science**



**People**



**Tools**



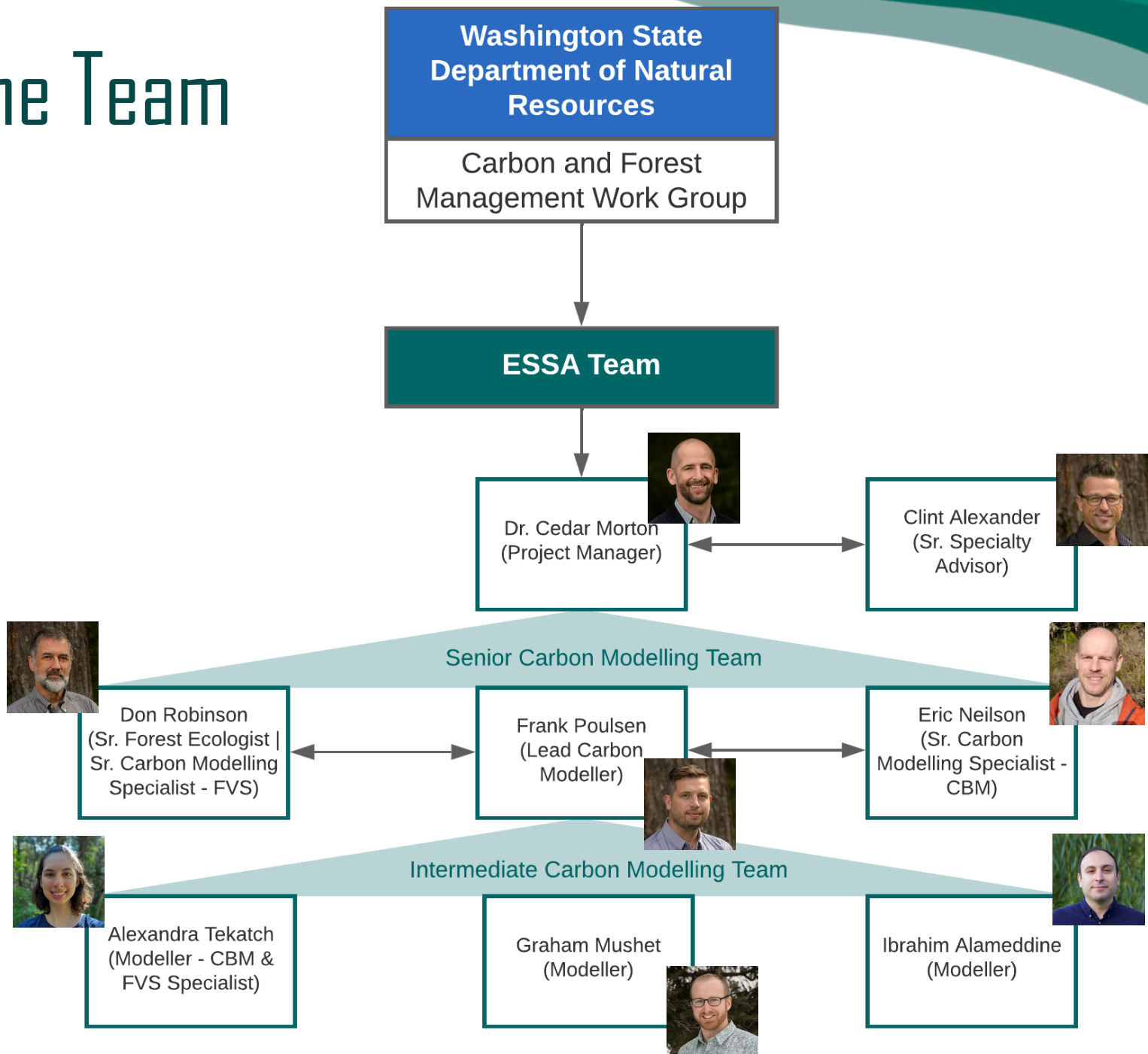
**ESSA**



# ESSA Technologies (ESSA)



# The Team



# Team Experience



**The Carbon Budget of the Canadian Forest Sector: Phase I**  
 W.A. Kurz, T.M. Webb, P.J. McNamee  
 ESSA - Environmental & Social Systems Analysts Ltd.  
 Vancouver, British Columbia, Canada

and  
**M.J. Apps**  
 Forestry Canada, Northwest Region  
 Northern Forestry Centre  
 Edmonton, Alberta, Canada

## Abstract

An assessment of the contribution of Canadian forest ecosystems and forestry activities to the carbon budget has been undertaken. The focus of this study consisted of the development of a computer modeling framework and the validation of published information to establish the sector's role as a net source or a net sink of atmospheric carbon.

The framework includes age-dependent carbon sequestration by living forest biomass, carbon litter fall of carbon to the forest floor, soil

of 2007 (Environmental and Social Systems Analysts Ltd., of Vancouver, British Columbia). ENFOR (ENergy from the FOrest) is a contract research and development program managed by Forestry Canada and aimed at generating sufficient knowledge and technology to realize a marked increase in the contribution of forest biomass to Canada's energy supply. The program was begun in 1978 as part of a federal initiative to develop renewable energy resources.

SCIENCE ADVANCES | RESEARCH ARTICLE

**APPLIED ECOLOGY**

**Natural climate change**

C. Ronnie Drever<sup>1,\*†</sup>, Susan C. Scott<sup>1</sup>, J. Davidson<sup>7</sup>, Raymond Ben Filewod<sup>11</sup>, Margot Hessing Tyler<sup>1</sup>, J. Lark<sup>15</sup>, Edward Le<sup>16</sup>, Sarin Brian McConkey<sup>19</sup>, Eric Neilson<sup>18</sup>, Sebastien Rodrigue<sup>18</sup>, Raju Y. S. Carolyn Smyth<sup>9</sup>, Naresh Thevaran Devon E. Worth<sup>8</sup>, Zhenyuan

## Development of FVS<sup>Ontario</sup>: A Forest Vegetation Simulator Variant and Application Software for Ontario

Murray E. Woods<sup>1</sup>  
 Donald C.E. Robinson<sup>2</sup>

**Abstract**—The Ontario Ministry of Natural Resources is leading a government-industry partnership to develop an Ontario variant of the Forest Vegetation Simulator (FVS). Based on the Lake States variant and the Prognosis<sup>SM</sup> user-interface, the FVS<sup>Ontario</sup> project is motivated by a need to address the impacts of intensive forest management strategies and the multiple ecological and social issues faced by today's resource managers. Currently, the large tree diameter model and the height model of the Lake States variant have been replaced with localized equations derived from data from the Great Lakes and Boreal forest zones of the province. A companion application, "Forest Manager" has also been created to develop FVS tree-lists from the data collected through field-cruising methods. Current efforts with the model involve the identification of weaknesses, improvement of user control on silvicultural treatments, and development of populating stand species- and diameter-distributions for inventory polygons through stand inventory attribution using high resolution digital imagery combined with LiDAR and Tree Crown classification approaches.

of Ontario, Canada, is made up of four main climatic forest types, namely: white pine and black spruce in the northern Hudson's Bay Lowland zone; white pine and black spruce in the Boreal forest zone; white and red pine and jack pine in the Great Lakes-St. Lawrence zone; and tolerant hardwood stands of the Deciduous zone (fig. 1). Productive forest management activities represent 53 percent (56.8 million hectares) of the province's forest base of 107.6 million ha. The leading species within the productive landbase and clearly black spruce (see table 1 for scientific names) and jack pine forests in the largest area, with shade-intolerant groups like poplar and white pine in an additional 18 and 9 percent respectively. Other important species between the Boreal and Great Lakes-St. Lawrence zones include white pine, and cedar which, when combined, account for about 6 percent of the leading deciduous species in the Great Lakes-St. Lawrence zone and smaller than the species leading in the Boreal zone: white pine, oaks, yellow birch, other hardwoods and eastern hemlock. Although these species represent 18 percent of the productive forest area, they account for 30 percent of Ontario's total productive forest area, and are managed with a wide range of silvicultural practices and systems.

Shade-intolerant species in the Boreal zone are most commonly managed with the clear cut silvicultural system (table 2), the management system that most closely represents natural wildfire disturbance; nature's regeneration method for these predominantly even-aged species which require full light conditions to regenerate and grow to maturity. Species like white and red pine, poor-quality tolerant hardwood forests and mid-tolerant species like oak and yellow birch are managed through the application of the uniform shelterwood system. The shelterwood system, with its series of partial cuts, best emulates low-intensity ground fire disturbances, which along with wind, is the dominant natural regeneration method for these species. Uneven aged tolerant hardwood stands of good stem quality and site quality are managed with the single-tree selection silvicultural system. The single-tree selection system, with its series of partial cuts, best emulates the gap-phase replacement dynamics that normally occur in these ecosystems.

Vol 452|24 April 2008 | doi:10.1038/nature06777

**Mountain pine beetle and forest carbon feedback to climate change**

W. A. Kurz<sup>1</sup>, C. C. Dymond<sup>1</sup>, G. Stinson<sup>1</sup>, G. J. Rampley<sup>1</sup>, E. T. Neilson<sup>1</sup>, A. L. Carroll<sup>1</sup>, T. Ebata<sup>2</sup> & L. Safranyik<sup>1</sup>

The mountain pine beetle (*Dendroctonus ponderosae* Hopkins, Coleoptera: Curculionidae, Scolytinae) is a native insect of the pine forests of western North America, and its populations periodically erupt into large-scale outbreaks<sup>1–3</sup>. During outbreaks the stand in a single year<sup>11</sup>. Timber losses are estimated to be more than 435 million m<sup>3</sup>, with additional losses outside the commercial forest<sup>12</sup>. The forest sector has responded by increasing harvest rates and reallocate some harvest, increasing the pine portion of the

nature  
**LETTERS**

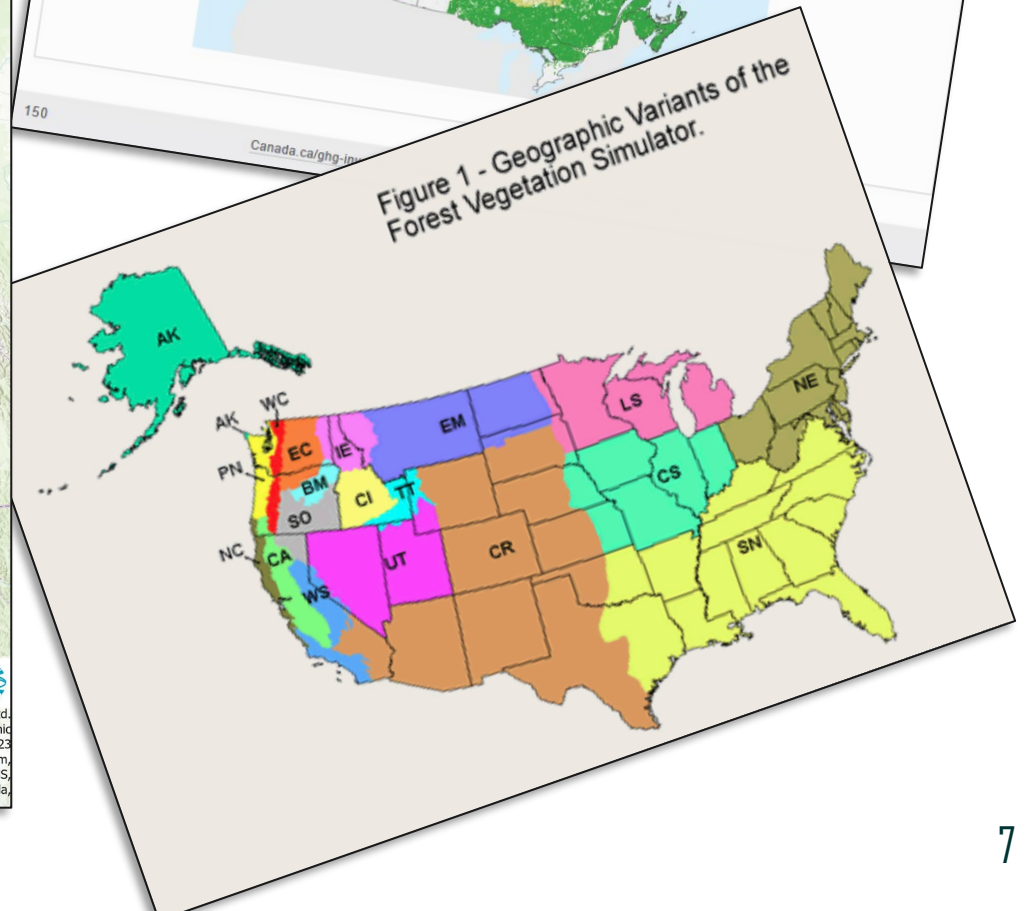
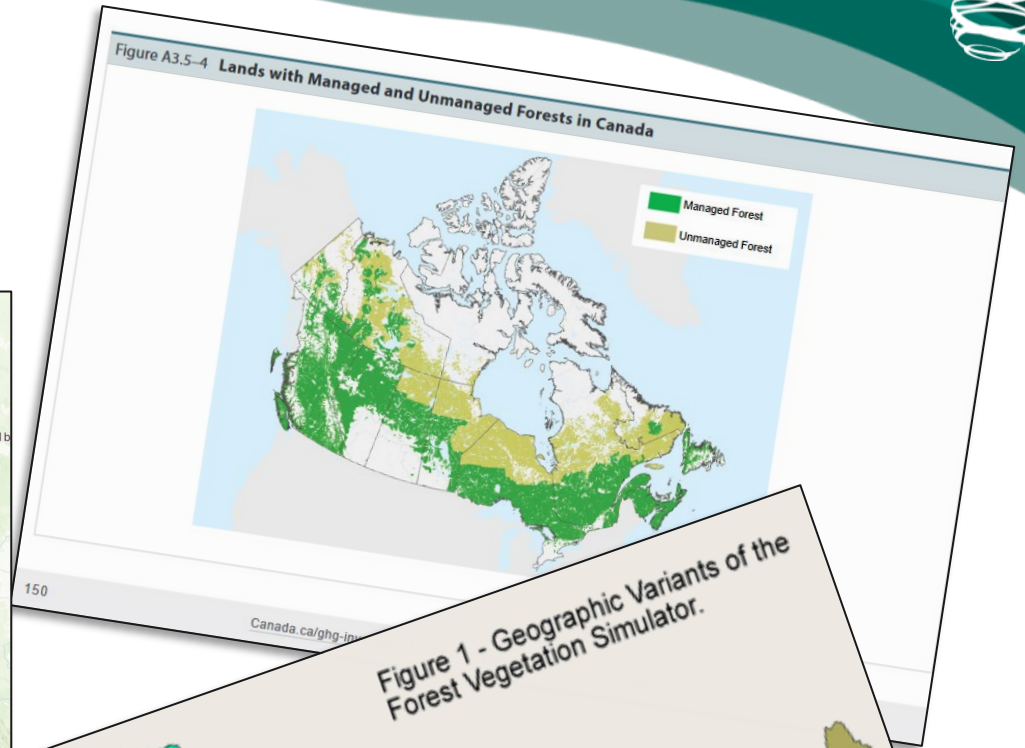
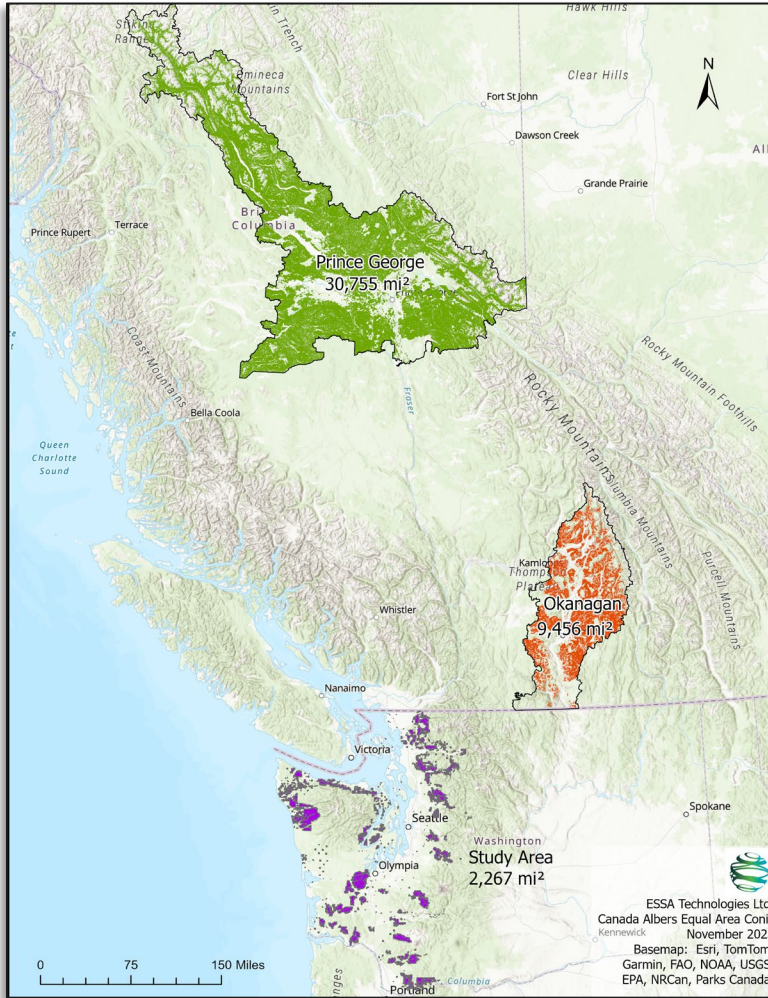
<sup>1</sup> Senior Analyst, Forested Landscapes, Ontario Ministry of Natural Resources, Bay Ontario; e-mail: murray.woods@mnr.gov.on.ca.  
<sup>2</sup> Senior Systems Ecologist, ESSA Technologies Ltd., Vancouver, B.C.; E-mail: drobinson@essa.com.

**Economic Valuation of Old Growth Forests on Vancouver Island: Pilot Study**  
 Phase I - Preliminary Assessment and Scoping  
**FINAL REPORT**

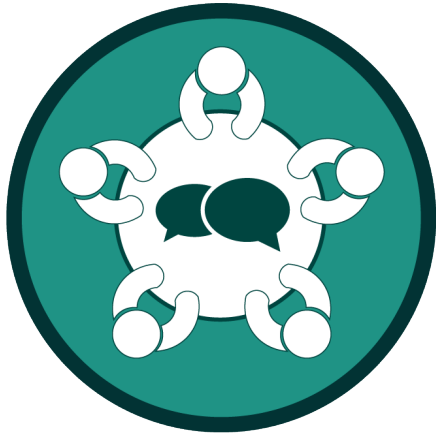
Prepared for:  
 Ancient Forest Alliance

ESSA Technologies Ltd.  
 Vancouver, BC Canada V6H 3H4  
 www.essa.com

# Team Experience



# Modeling Tool Selection



Work Group communicates modeling needs (i.e., what forest carbon questions would you like to answer?)



ESSA

ESSA evaluates models with help of Work Group input & makes recommendation to DNR



DNR selects preferred modeling tool



# Example Assessment Rubric (*Might Use*)



Criteria	Importance	MODEL #1	MODEL #2	#1 Score	#2 Score
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## Work Group Input (WHAT WE HEARD)

Criterion #1	?	H	H	TBD	TBD
Criterion #2	?	H	M	TBD	TBD
Criterion #3	?	H	M	TBD	TBD
Criterion #4	?	M	H	TBD	TBD
Criterion #5	?	H	H	TBD	TBD

## Modelling Team Assessment

Criterion #1	?	H	H	TBD	TBD
Criterion #2	?	H	M	TBD	TBD
Criterion #3	?	L	L	TBD	TBD
Criterion #4	?	H	L	TBD	TBD
Criterion #5	?	M	H	TBD	TBD
Criterion #6	?	L	H	TBD	TBD



# Intro to the Carbon Modeling Tools

**CBM**  
**CFS** **3**



**Both align with IPCC Tier 3 guidelines**

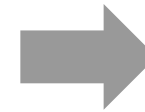


# Basic Model Process (Both Models)

Stand  
Initialization



Simulation

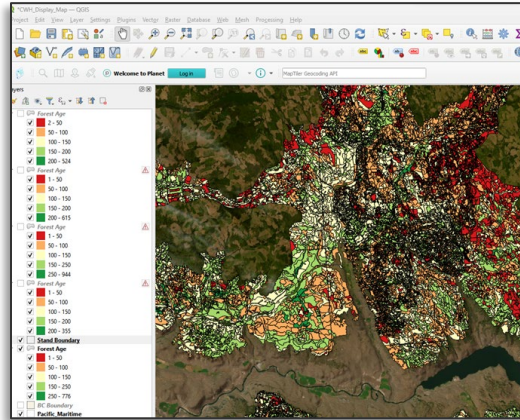


Post-  
processing

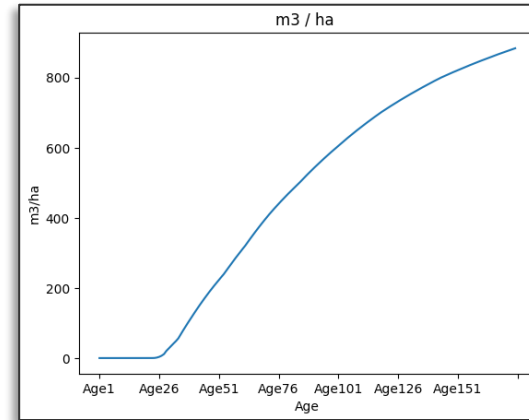


- Growth
- Carbon fluxes
- Disturbance
- Harvest

# Inputs (Both Models)



Forest Inventory  
(e.g., FIA)



Tree Growth



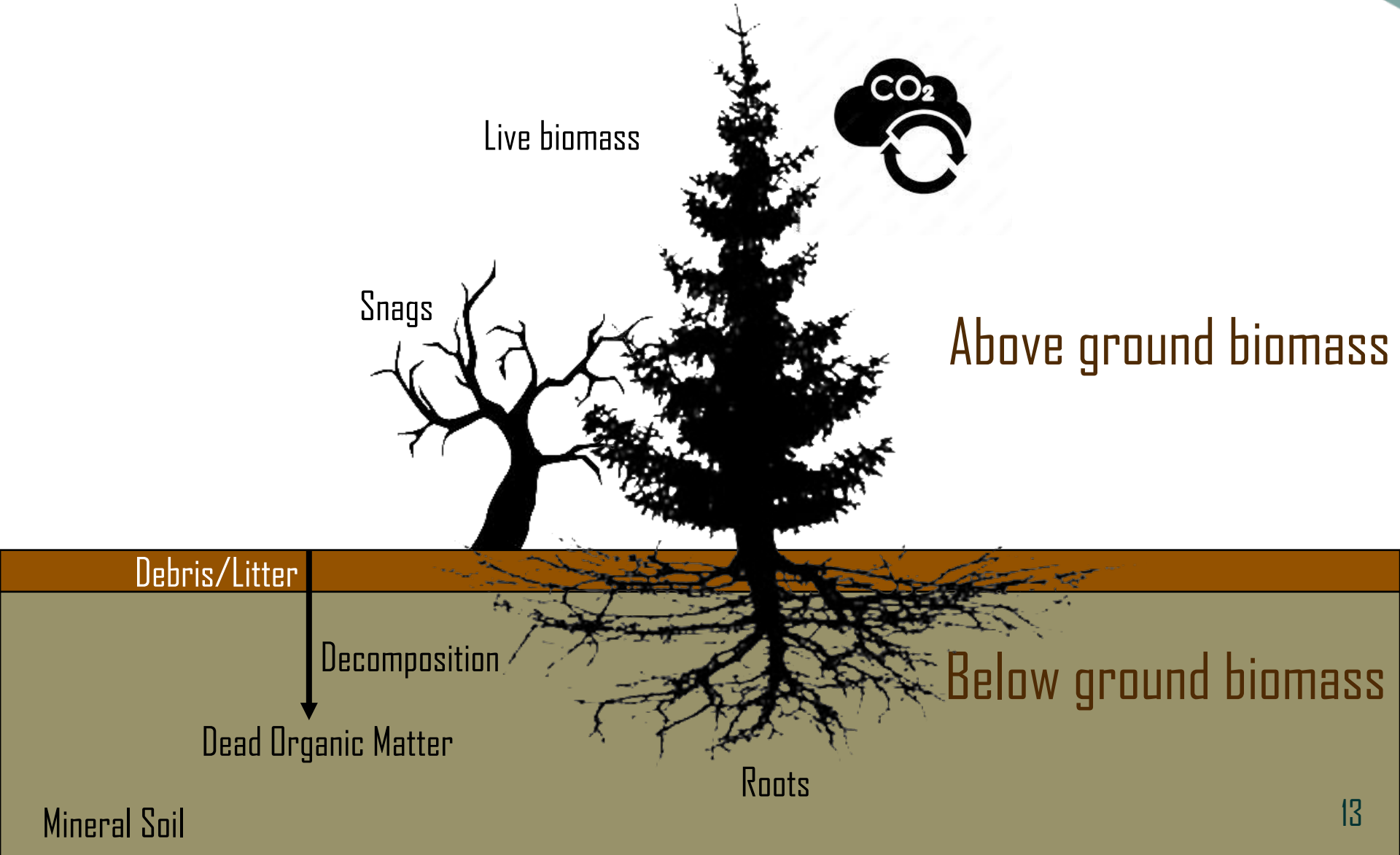
Disturbance Rules



Harvest Rules



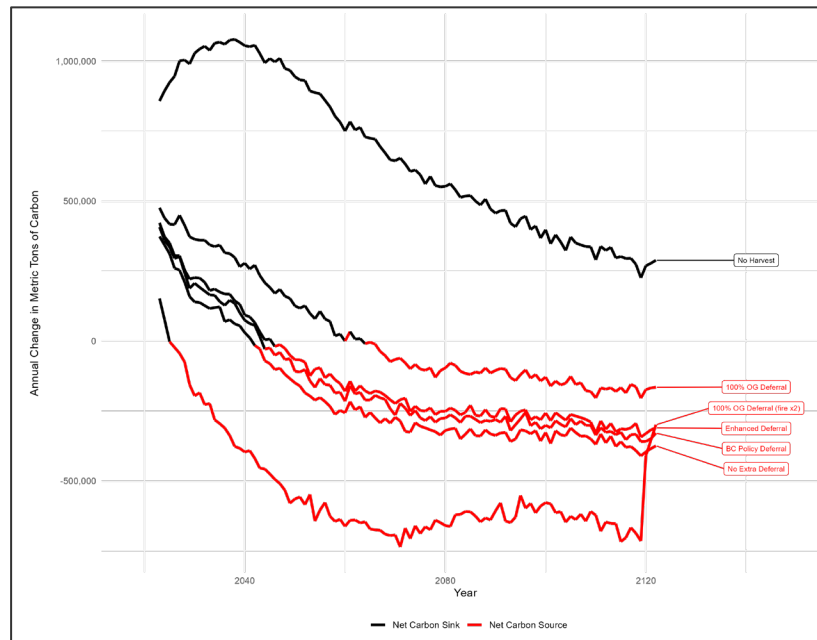
# Carbon Pools (Both Models)





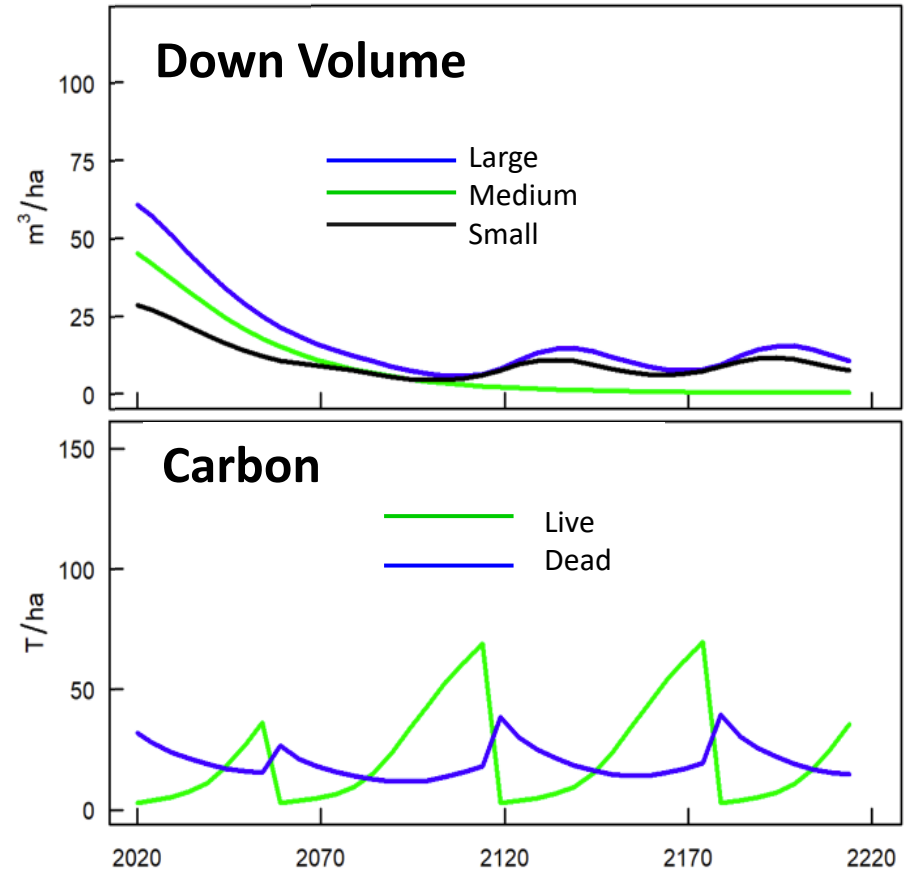
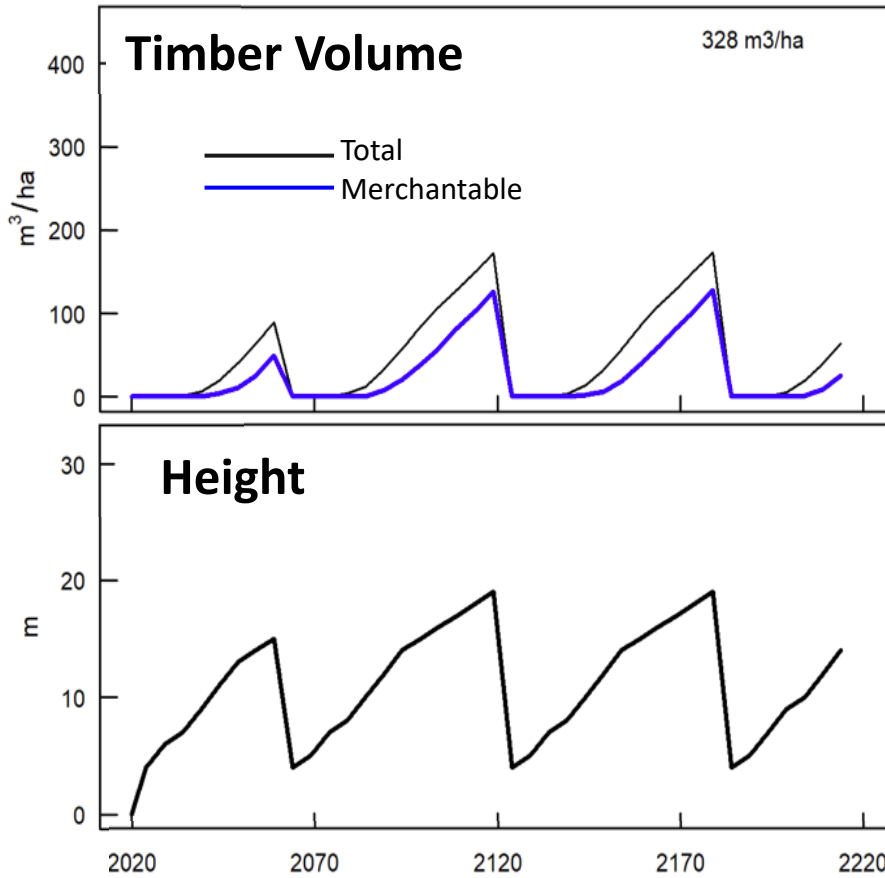
# Outputs (CBM)

- tC in harvest (can be converted to tC/ac or ft<sup>3</sup>)
  - Can be disaggregated by leading species, or other stand-level characteristics
- tC to a general wood products pool
- Custom carbon and timber volume outputs can be generated





# Outputs (FVS)



# Key Differences



Vs.



Simpler harvest (by stand, less capable of representing thinning but can be done in a rudimentary way)

More detailed harvest (tree level, e.g., can include thinning)

Simpler outputs in tC by pool, softwood/hardwood bins, leading species

More detailed live and dead biomass/carbon outputs for stem, crown, roots

Simpler climate change via fire rates, decay temperatures or adjusted growth curves

Climate change driven by GCM: changes to site productivity, carrying capacity and species tolerances

Simpler wood products representation (softwood/hardwood)

More detailed wood products representation (species, size)

Less input data needed (if available, but extra effort if not)

More input data needed

Generally faster computation per run

Generally slower computation per run (e.g., 2-5 sec/stand)

Annual time steps, no limit

5- or 10-year time steps, max 40 steps



Q&A



**CBM**  
**CFS** **3**



Your Turn!  
Clarifying questions



# Supplementary Slides

Attribute	FVS	CBM.CFS3
<b>Developer/maintainer</b>	USDA Forest Service	Canadian Forest Service
<b>Year developed</b>	1973	Original model: 1989; CBM-CFS3 model: 2002
<b>Model type</b>	Individual tree model; semi-distance independent	Stand and landscape-level model; distance independent
<b>How are forested regions specified?</b>	Includes 22 different model variants depending on region.	Default ecological parameters are provided, but can be modified by the user.
<b>Time step</b>	Default cycle length is 10 years for most variants.	Annual
<b>Can forest management and disturbance be analyzed?</b>	Yes	Yes
<b>Includes climate change?</b>	Yes, but only for Western US with Climate-FVS	No. But user can modify the default climate data (which only impacts decay), and use zero carbon impact disturbance events paired with transition rules to alter stand growth in unison with changes in climate.
<b>Incorporates uneven-aged stands?</b>	Yes	No. But user can modify yield curves.
<b>How is regeneration handled?</b>	A "full" regeneration establishment model is available for some variants in the western US. A "partial" establishment model is available for all other variants and simulates stump sprouting. User can specify information on planting and natural regeneration.	Following a stand-replacing disturbance, regeneration will occur automatically, or can be delayed or accelerated using transition rules and/or switching of growth curves. By default, there is no regeneration assumed following non-stand-replacing disturbances. However the user can implement a transition rule to switch an impacted stand to a new growth curve(s) to account for multiple growth components (although the stand can only be represented by a single age or age class).
<b>Includes harvested wood products report?</b>	Yes	No. But annual carbon stocks harvested and transferred to a forest products pool are tracked, and can be viewed and exported for use in HWP carbon models.
<b>How does it incorporate carbon?</b>	Accounts for carbon stocks and stock changes with the Fire and Fuels Extension.	Accounts for carbon stocks and stock changes in tree biomass and dead organic matter pools.





# Wood Products

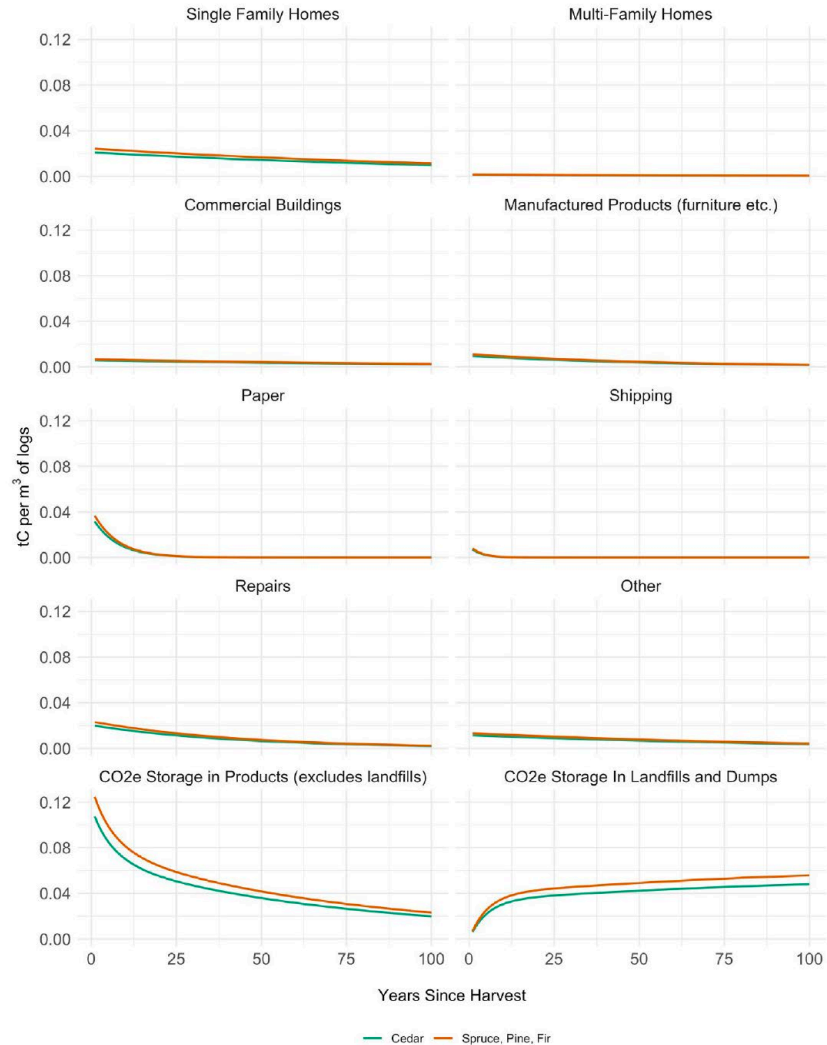
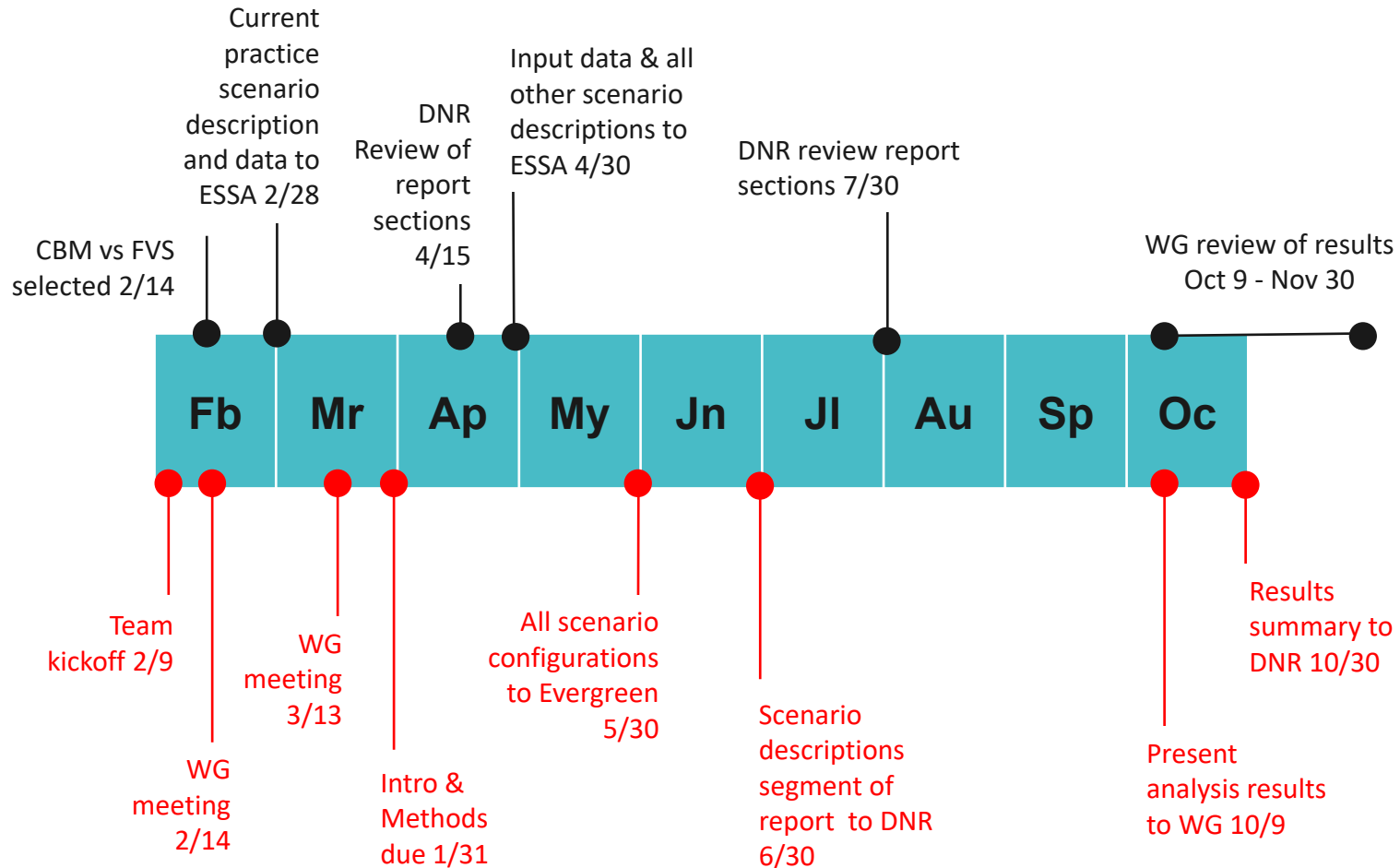


Figure 8. Carbon stored in wood or paper products for 1 m³ of harvested logs



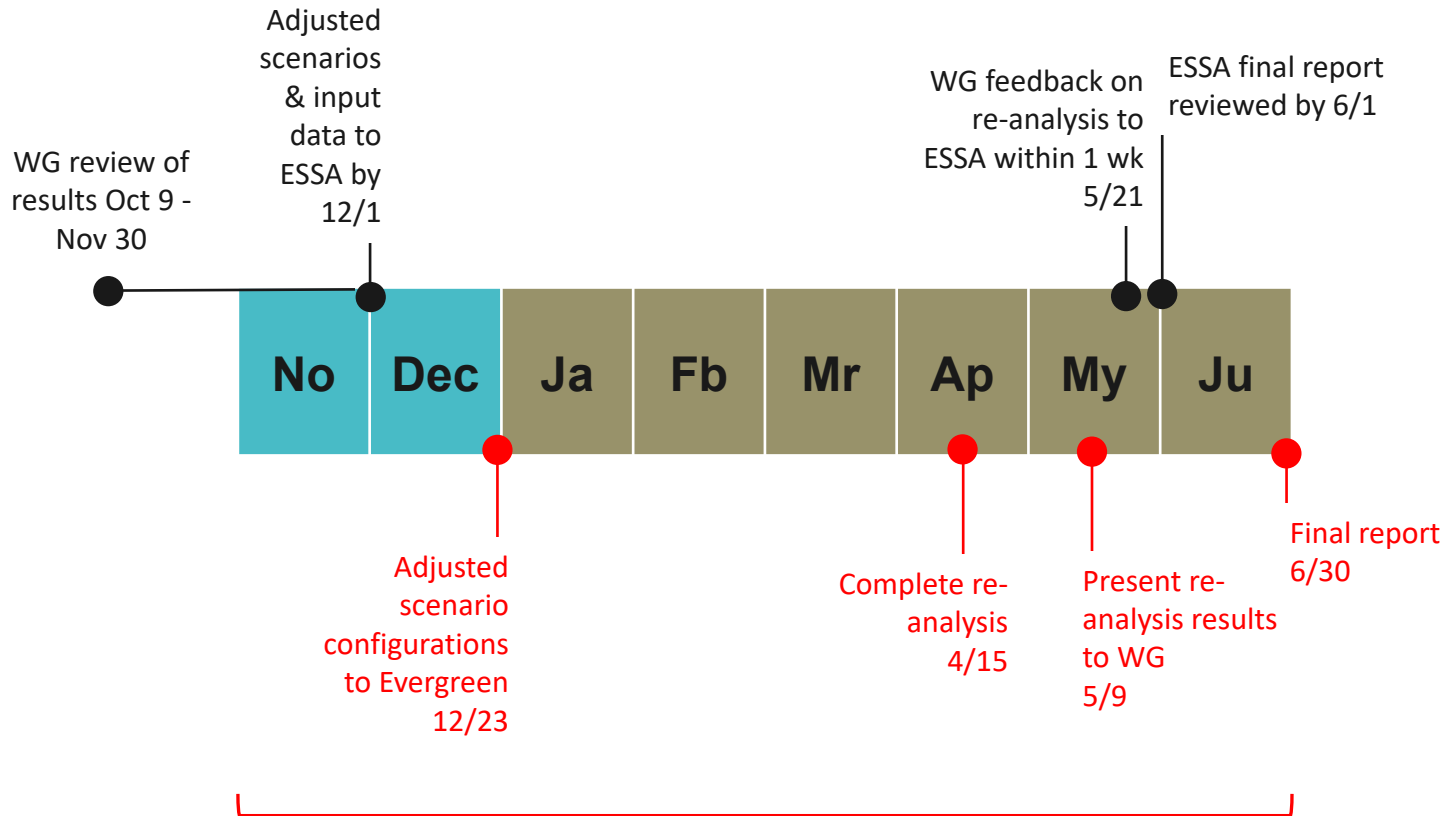
# Phase 1 - Modelling



Attend WG meetings and provide progress reports as needed



# Phase 2 - Refinement & Finalization



Attend WG meetings and provide progress reports as needed

# Answers to Big Questions

- How much timber is harvested **by species** over time?



- Hardwood
- Softwood
- Extra processing for species outputs



- Cedar
- Fir
- Balsam
- Pine
- Cottonwood
- Etc..

# Answers to Big Questions

- How does **silviculture** affect results over time?

**CBM  
CFS 3**

- E.g., can remove hardwood to represent thinning



- E.g., can remove species, small trees, large trees



# Answers to Big Questions

- How much **carbon and timber** at end of time period?



- Tons of carbon/acre
- ft<sup>3</sup> of timber via conversion factor
- Hardwood / softwood



- Tons of carbon/acre
- ft<sup>3</sup> of timber natively
- Mbf ('000s board feet)
- By species

# Answers to Big Questions

- How does **climate change** affect results?



- Adjust growth curves
  - Adjust wildfire and/or pest rules
  - Can't do dynamic changes in carbon decay rates
  - Can represent temp but not precip in carbon decay
- Growth-yield & carrying capacity, and site quality all change
  - Adjust wildfire and/or pest rules
  - Can't do dynamic changes in carbon decay rates

# Answers to Big Questions

- What **input data** do I need to provide?



- Forest inventory
- Volume/age per stand
- Growth-yield curves compiled from FIA data
- Fire return intervals
- Pest disturbance rules
- Harvest rules

- Forest inventory
- Individual tree (density, diameter, species)
- Growth-yield curves directly from FIA data
- Fire return intervals
- Pest disturbance rules
- More complex harvest rules

# Answers to Big Questions

- What **forest products** are generated?



- Wood products
- carbon pool
- Can be done with post-processing



- Wood products
- carbon pool (by species, size)



# Modeling Phases

Work Group  
Review



	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Phase 1 - Modeling	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
Phase 2 - Refinement & Finalization	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█



ESSA data preparation, model setup, and modeling of current practice case plus alternative management scenarios



ESSA refinement of modeling and final reporting